# SALINE WATER PROGRAM

## (RESEARCH AND DEVELOPMENT)

UNIVERSITY
OF MICHIGAN

AUG 12 1958

MAIN
READING ROOM

# HEARINGS

BEFORE A

# SUBCOMMITTEE OF THE COMMITTEE ON GOVERNMENT OPERATIONS HOUSE OF REPRESENTATIVES

EIGHTY-FIFTH CONGRESS

SECOND SESSION

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# SALINE WATER PROGRAM

## (Research and Development)

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TUESDAY, APRIL 15, 1958

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON PUBLIC WORKS AND RESOURCES,
OF THE COMMITTEE ON GOVERNMENT OPERATIONS,
*Washington, D. C.*

The subcommittee met, pursuant to call, in room 1501, New House Office Building, at 10 a. m., Hon. Robert E. Jones (chairman of the subcommittee) presiding.

Present: Representatives Jones, Fascell, and Knox.

Also present: Arthur Perlman, staff administrator; Phineas Indritz, counsel; Miles Q. Romney, professional staff member; and J. P. Carlson, minority counsel.

Mr. JONES. The subcommittee will come to order.

In the public hearings which begin today, this subcommittee will examine the progress being made by the Office of Saline Water of the Department of the Interior in its program of research and information concerning production, at economical costs, of fresh or potable water from sea water or brackish inland waters.

The development of economical methods to make such waters potable would greatly benefit not only our country, but the whole world. Vast areas with water scarcity could be made more productive, for industrial, domestic, and perhaps even for agricultural use, to provide a better livelihood for millions of people.

Techniques for separating salt and water have been known for generations. Their great drawback is their expense. Recognizing the importance of research and development to bring down the cost of desalting, President Truman, in March 1950, requested the Secretary of the Interior and other Department heads to collect all available information on large-scale conversion of salt water, and to seek legislation for such purposes.

In the Saline Water Act of July 3, 1952, Congress directed the Department of the Interior to engage in a 5-year program of research and development to create "practicable, low-cost means of producing from sea water, or from other saline waters, water of a quality suitable for agriculture, industrial, muncipal, and other beneficial consumptive uses."

In 1955 Congress broadened the law into a 14-year program with an authorization of $10 million, and directed increased coordination with other Federal agencies and with public and private agencies in foreign countries. The conference report on the 1955 amendments shows that

Congress believed "that national and international conditions require that the program be expedited," and that in view of "the imperative need for spending the objectives of this program" it "cannot be allowed to drift along without producing concrete results."

Although progress has been made in some respects, there have been complaints that the program is not proceeding with the urgency that Congress intended; that the Office of Saline Water is understaffed and insufficiently supported, and that research and development on pilot plant scale is lagging.

In these hearings, the subcommittee will hear testimony from Federal officials concerning the present status of the Nation's water supplies and needs, and the extent, economy, and efficiency of the Government's efforts on saline water conversion research and development. The subcommittee has received statements and letters from many persons and companies concerned with saline water conversion and will hear testimony from a number of them. The subcommittee hopes that these hearings will help to develop more quickly low-cost water for domestic, industrial, and agricultural uses from sea and brackish water.

Our subcommittee counsel, Mr. Phineas Indritz, has a list of relevant letters, statements, and other documents concerning the subject matter of this hearing which have been submitted to the subcommittee, and without objection I shall ask him to present the list to the reporter at some subsequent time, when they will be made a part of the record.

We have received statements from two Members of Congress, Mr. Cecil R. King, of California, and Mr. James Roosevelt, also from the same State.

(The statements of Representatives King and Roosevelt are as follows:)

STATEMENT OF HON. CECIL R. KING, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Mr. Chairman, it is evident that the task of developing economically feasible saline water conversion processes provides one of the great challenges to American scientists and engineers. It is equally evident that the successful attainment of the objectives of the saline water program will ultimately serve the expanding populations and new industrial empires of the world as few other achievements can do. Both in America and elsewhere, successful processes for the conversion of sea water could render many water-poor areas productive and prosperous.

These present hearings before your subcommittee, the recent Senate hearings conducted by Senator Clinton Anderson's committee, and the number of Members introducing legislation on the subject are evidence of the interest of the Congress in expediting action on this important problem.

I would like to stress the importance of the saline program—particularly in my own area in California on Santa Catalina Island where the need for water is most urgent.

In the report of the Department of Interior on my bill, H. R. 11405, providing for construction of a full-scale demonstration plant on Santa Catalina Island, Calif., for the production of fresh water from salt water, it was stated: "Among the emerging potentialities for lower cost conversion is the use of low temperature heat derived from nuclear reactions for use in saline water distillation and other conversion plants."

Inasmuch as the major expense item in sea-water conversion is the cost of power or energy, my bill specifically provides that the demonstration plant may be constructed in combination with a steam electric powerplant or a nuclear reactor as the source of thermal energy, if it is determined that such addition will result in the reduction of conversion costs. It also provides for an appropri-

ation of $10 million, and that the Secretary of Interior is authorized to negotiate and enter into agreements with the State of California, and other appropriate parties providing for the construction and operation on Santa Catalina Island, Calif., of a full-scale salt-water conversion demonstration plant designed to produce not less than 10 million gallons of fresh water per day, and that the conversion process to be demonstrated shall be selected from the most promising process known for full-scale conversion, and shall be agreed upon by the Secretary and the State of California.

Santa Catalina Island would be an exceptionally good location to demonstrate the practical use of sea-water conversion as the water could immediately be put to very beneficial use by the city of Avalon, located on the island, to alleviate its acute shortage of water.

Several years ago, Catalina was seriously considered as one of the areas adjacent to Los Angeles to be used for mass evacuation of the coastal population in case of enemy action in the southern California area. A plan was set up by Los Angeles County in connection with the Civil Defense Authority for such use but, mainly due to lack of fresh water on Catalina Island, no further action was taken on this important program.

There is a constant water shortage at Catalina and, for several extended periods within the past 10 years, it has been necessary for the city of Avalon to adopt a water rationing ordinance because of the lack of sufficient fresh water to meet the needs of its permanent population, and its hundreds of thousands of tourists and vacationers. Just before the recent heavy rains, it was necessary to place the city of Avalon on a 50-percent water rationing basis and if no rainfall had occurred, the city would have been completely without water. For many years the island has been compelled to use salt water for sanitation purposes and fire protection.

The residents of Santa Catalina Island are now paying the highest water rate in the United States and their desperate need for water prevents them from using their very rich soil for agriculture. An increase in their water supply would enable them to produce their own food, which now must be transported from the mainland by boat.

Santa Catalina Island is one of the largest undeveloped recreational areas on the Pacific coast although it is within 22 miles of many highly populated cities of southern California. Los Angeles County alone, of which Catalina is a part, contains more population than 40 of the 48 States of the Union. Lack of fresh water has prevented extensive development of Catalina as a recreational area.

The small boating industry has an urgent need for the development of a nearby recreational area to provide a destination for the boating public. Small-boat operations at the present time support a multi-million-dollar industry in southern California. Evidence of the strong desires of the boating public to utilize Catalina as a place for recreational activities can be shown by the influence which they brought to bear in the cancellation of a Navy lease for a small portion of Catalina 5 years ago. A lease had actually been consummated with the Navy for national-defense purposes and the demand and pressure of the boating public caused the Secretary of the Navy to relinquish this location.

For many years, Catalina has been the popular location for seaside youth camps such as Boy Scouts, Girl Scouts, YMCA, church groups, etc. The major limiting factor has been the lack of adequate fresh water. If ample water were assured, many more camp sites could be established on Catalina to accommodate the tremendous demand in this area for youth camping caused by the increasing scarcity of available camp sites on the mainland.

My bill further provides that in recognition of the urgency of finding ways and means of economically converting salt water to fresh water, the negotiations authorized by this act shall be concluded and construction of the demonstration plant shall be undertaken at the earliest possible date.

I am convinced that the time is at hand for accelerated action in connection with the saline water program, and believe it of interest that the Maxim Silencer Co. of Hartford, Conn., before the Senate committee, submitted a statement to clarify their belief that practical designs exist today with which to produce large-size demonstration plants, stating that the time has definitely come to build such plants to prove the practicability of the idea and to assist in the further development of the art.

The Congress must take the leadership in the saline water conversion program by providing funds for full-scale demonstration plants that will point the way to a permanent solution of the problem, and your committee is to be commended for its efforts toward this important objective.

STATEMENT OF HON. JAMES ROOSEVELT, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Mr. Chairman, I very much appreciate this opportunity to appear before you to present a statement of my impressions of the operations of the Office of Saline Water. My interest in the functions of the Office stems partly from my bill, House Joint Resolution 545, to set up demonstration plants for the conversion of saline water; and from my greater concern for the Nation's water resources.

My concern is shared by the most knowledgeable Department of the Interior itself, and for the record I would like to quote from a report of March 27, 1958, signed by Assistant Secretary of the Interior Aandahl, on my bill and those similar to it.

"It is evident that the task of developing economically feasible saline water conversion processes provides one of the great challenges to American science. It is equally evident that the successful attainment of the objectives of this Department's saline water program will ultimately serve the expanding populations and new industrial empires of the world as few other achievements can do. Within our country, 21 of the 48 States border on the sea coast, and contain more than 55 percent of our population and 65 percent of our industries. Furthermore, the scarce remaining supplies of fresh water in many of our inland areas can be augmented very substantially if their brackish waters can be desalted economically. Both in America and elsewhere, successful processes for the conversion of sea or brackish waters could render many water-poor areas productive and prosperous. Within friendly countries outside the United States there are many regions lacking adequate sources of fresh water which might be supplied from desalted sea of other salty sources. Some of these areas are in the Middle East, North Africa, Latin America, Spain, Greece, Italy, Australia, and even in such countries as Iceland and Ceylon."

Mr. Chairman, to me this is a most compelling statement of the need for a vital program, productive of concrete result. And yet, from the inception of the program in 1952, results consistent with the aims of the program and with the resources and abilities available have not been forthcoming. Further, the report from which I quoted recommends against the construction of demonstration plants at this time, favoring instead further research, and pilot plant construction. Placed in juxtaposition with Mr. Aandahl's appreciation of the need for processes for saline water conversion, I fail to see why the opportunity that is presented by a large additional appropriation for demonstration plants is not seized, and put to work to implement the research and testing of the last 10 years.

I am told that the restrictions under which the Office of Saline Water operates mitigate against its success. For one thing, its professional staff is too small to be able to cope effectively with the volume of work. The hearings of the House Appropriations Committee to consider the appropriation for the Department of the Interior for 1959 presented the Office of Saline Water with the opportunity, which I would assume that it desired, to request more money for administration, in order to carry out better the aims of the program. And yet, in testimony, Mr. David Jenkins, Director of the Office, testified as follows:

"Here we see that there is included in the total limitation some $2 million for the 14 years for this purpose. During the first 6 years, and an estimated amount for the final 3 years, there will be needed about $920,000, leaving $1,080,000 available for appropriation in these present busy 5 years, or $218,000 a year.

"We are requesting, though, only $165,000. I do hope that the committee will allow this minimum amount."

Certainly these remarks do not typify an attitude best designed to encourage results, and to push ahead with the enthusiasm and vision that I believe this program deserves. If the Department of the Interior does not support its own activities vigorously, the job of Congress is indeed made more difficult when the time comes to vote appropriations.

It is disturbing that no work is being done in conjunction with foreign firms, even though we know that progress is being made in the development of techniques and processes for conversion in other countries—nor have I heard any adequate justification for this failure.

I do believe that the limitations that were imposed on the appropriations for the Office of Saline Water by the 1955 amendment to the act has had an extremely unfortunate inhibiting effect on the program. They should be removed as part of a drive to revitalize the operation.

But if conversion of saline water is to become an operating fact, it will depend primarily on the extent to which the Office can revitalize itself. I commend this committee for its interest, and I sincerely hope that as a result of its deliberations constructive action will be taken to invest the Office with the vigor that it must have, and that greater support for its programs will be forthcoming from all quarters.

Mr. JONES. We have as our first witness this morning Mr. Fred G. Aandahl, Assistant Secretary of the Interior for Water and Power. Mr. Aandahl, we are delighted to have you today, sir, and if you will come forward we will be glad to receive your statement, Mr. Secretary.

**STATEMENT OF FRED G. AANDAHL, ASSISTANT SECRETARY OF THE INTERIOR FOR WATER AND POWER; ACCOMPANIED BY DR. LUNA B. LEOPOLD, CHIEF HYDRAULIC ENGINEER, GEOLOGICAL SURVEY; DAVID S. JENKINS, DIRECTOR, OFFICE OF SALINE WATER; ERNEST H. SIEVEKA, OFFICE OF SALINE WATER; DR. WILLIAM S. GILLAM, CHIEF, BRANCH OF RESEARCH, OFFICE OF SALINE WATER; JOSEPH J. STROBEL, CHIEF, BRANCH OF ENGINEERING, OFFICE OF SALINE WATER; ALLEN CYWIN, ASSISTANT CHIEF, BRANCH OF ENGINEERING, OFFICE OF SALINE WATER; AND PAUL H. GANTT, OFFICE OF THE SOLICITOR, DEPARTMENT OF THE INTERIOR**

Mr. AANDAHL. Mr. Chairman, I have a brief statement I would like to read.

We in the Department of the Interior are pleased to appear in response to your request to provide further information on progress of research and development in saline water conversion.

Responding to your earlier requests for information, the Department has furnished statements on various phases of the program including a description of known processes of conversion, their possibilities for future success, estimates of conversion costs, a statement of our functions, a summary of each research project undertaken and the cost thereof, projects considered ready for pilot plant or larger-scale testing, funds that would be needed for testing on such projects during the next 2 years, the Secretary's advisory board's functions and recommendations, and related subjects.

This program for saline water conversion was authorized by the act of July 3, 1952, as amended June 29, 1955.

An authoritative statement of the goal of this program is found in the act of July 3, 1952:

* * * to provide for the development of practicable low-cost means of producing from sea water, or from other saline waters, water of a quality suitable for agriculture, industrial, municipal, and other beneficial consumptive uses on a scale sufficient to determine the feasibility of the development of such production and distribution on a large-scale basis.

This objective is carried out by means of research grants and contracts made to or with chemists, physicists, engineers, educational institutions, scientific organizations, or industrial or engineering firms, to conduct research and technical development work.

At the beginning of the program in 1952, much thought was given to the cost of converted water which should be considered as the initial

goal of the research program. In view of the great range in water costs for the many different uses and locations, it was obviously difficult to set up precise cost goals, nor were such precise cost goals specifically needed for the purposes of the research program. In the judgment of all concerned, however, it was concluded that the initial conversion cost objective for each of the various end uses should approximate the maximum cost of water for that use when supplied from other sources.

It was believed that if these costs criteria could be approached or reached within a reasonable period by the falling cost of conversion being brought about through research, continued efforts to reduce conversion costs would be justified. The interest in the subject of maximum prices being paid for water for irrigation, municipal and other purposes, which was shown at the House hearings in 1952 on the Saline Water Act, was in line with our thinking on these initial objectives. The initial target for converted saline water for irrigation uses was set at about $40 an acre-foot because that was the highest known price being paid for irrigation water at that time.

Mr. KNOX. May I interrupt?

You speak here of $40 an acre-foot. Would you put in the record the approximate amount of water that is involved in an acre-foot?

Mr. JONES. Off the record.

(Discussion off the record.)

Mr. AANDAHL. There are 326,000 gallons in an acre-foot.

Mr. KNOX. Thank you.

Dr. GILLAM. That is approximate.

Mr. AANDAHL. Likewise the objective cost for converted water for municipal uses was set at about $100 an acre-foot (30 cents a thousand gallons), since a few communities were on record as having paid about that much for wholesale undistributed water at the city's intake. Even a conversion cost in the neighborhood of 50 to 60 cents per thousand gallons for wholesale undistributed water may lead to some municipal use, especially to supplement deficient present supplies.

The permissible cost and cost range for industrial water are much greater, but cost data comparable to those for municipal and irrigation uses are not available. It seems probable that industrial uses will come first in utilizing converted saline water since some industries can afford to pay more than can be justified for irrigation or municipal uses at present. Some industrial uses of converted sea water are already being made as in California, where the Pacific Gas & Electric Co. is converting sea water for its boilers at one of its plants at about $650 an acre-foot ($2 per thousand gallons). From this it is evident that as conversion costs are reduced below this figure, to within the range of $1 per thousand gallons, other industrial uses will find conversion economical.

I believe we should bear in mind that the initial utilization of a saline water conversion process for a particular water supply need will occur when the cost of conversion compares favorably with the cost which would be experienced in meeting the same need from an available alternative source at the time the need is felt. Therefore, while historical costs of water supplies for various uses may serve as rough indications of target figures, the competitive cost level to be met by a conversion process will be determined in the light of the circumstances prevailing at the time and place of the proposed installation.

The progress that has been made over the relatively short span of this program has been substantial. Progress during the past few years has been such that the initial period of exploratory research in the laboratory must now in part be replaced by pilot-plant operation and field testing of the more promising processes. The status of development in each of the various processes will be described to the committee by our technical witnesses. We are aware, however, and I am sure many in the industry are aware, that much remains to be done before maximum results are attained.

As we continue our efforts we are supported by the commendation and the constructive suggestions of our advisory committee on saline water conversion, comprised of experts in the field of research and development.

The authorized program was designed to encourage research and development in this general area, with a view to obtaining the greatest practicable participation of knowledge and skill from all sources. Some results of this stimulation of technical interest became apparent in the resent International Symposium on Saline Water Conversion, held in Washington under joint sponsorship of the National Academy of Sciences-National Research Council and the Office of Saline Water. More than 300 scientists and engineers working in this field, from 16 countries in addition to the United States, took part, presenting 39 scientific papers, which brought out a large number of scientific ideas and views.

The immediate need, as I see it now, is to put more of the promising processes under initial pilot-plant testing and a few of these processes that respond the best in larger follow-up pilot-plant testing. Some processes will require fairly large plants for the initial tests. We feel it is better to avoid concentration on 1 or 2 processes and provide sufficient flexibility to accommodate various processes in order to provide answers to the complex problem of providing fresh water from different qualities of saline water, in different locations, for a variety of end uses, and in widely varying quantities.

There is still much to be learned about the refinement and efficiency of a number of promising processes that can be attained only by continued research and pilot-plant testing. At present our greatest contribution to the program can come in that area rather than in the construction of 1 or 2 large production plants even though they might be intended primarily for demonstration purposes.

I am accompanied by Mr. David S. Jenkins, Director, Office of Saline Water, together with members of the technical staff of that Office, and Dr. Luna Leopold of the Geological Survey. They will be pleased to offer further testimony for the information of the committee.

Congressman, may I add that my statement has purposefully been quite general. The other witnesses are going to follow with more detailed explanations of what is being done in the Office of Saline Water, and give you information about some of the programs that are under way.

Now I suggest it might be helpful to the committee to have their papers and their presentations before we go into any broad questioning period.

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Mr. JONES. Mr. Secretary, I thank you for leading into it gently, because it is a new subject to us. If you were to take off on a technical angle, I am sure we would be lost before we got very far with you. So we will go to school with you, sir.

Mr. AANDAHL. I might say, Mr. Chairman, if I were to attempt to get too deeply into the technical phases of the work, I would be lost, too.

Mr. JONES. Mr. Knox.

Mr. KNOX. I think I should withhold any questions until we have had an opportunity to hear from the rest of the gentlemen who are accompanying the Secretary at this hearing this morning.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. I have some general questions, Mr. Secretary. I shall not get too deeply into the technicalities at this point.

Do you consider that the present legislation authorizes the Department to carry a saline water conversion process through the design, fabrication, and operating stages of a pilot plant?

Mr. AANDAHL. Yes, I do.

Mr. INDRITZ. Do you believe that the legislation also encompasses carrying the process through to a demonstration plant?

Mr. AANDAHL. I would doubt that.

Mr. INDRITZ. Would you indicate the difference between the pilot plant and the demonstration plant so that the committee may be aware of how the Department regards the distinction between them?

Mr. AANDAHL. A pilot plant is one that is built primarily for the purpose of evaluating what can be done with the information that is then available, and also for the purpose of pointing out what additional research and what additional refinements might be necessary in that process before it approaches the ultimate goal that the program has in mind.

On the other hand, I think of a demonstration plant as one that embodies a process and equipment that the office would feel is pretty well perfected. That is, there always could be room for additional improvement, but it would be a plant that is pretty well perfected, and one in which we are ready to demonstrate to the public, "Here is what we can do." We are ready to recommend this as something for wide-scale use.

Mr. INDRITZ. Even where a process is nigh perfected, are there not times when there may have to be studies made as to the engineering costs and whether the engineering is adequate?

Mr. AANDAHL. I am not sure I quite understand you.

Mr. INDRITZ. Is there not a stage between having a process completed on its research stage and actually going into full-scale commercial production?

Mr. AANDAHL. Yes, there is, and when pilot plants indicate their capability of approaching the ultimate goal in cost production, why, a study needs immediately to be made of the engineering design and the cost of the larger plant, because the smaller pilot plant in itself will not be able to attain the efficiency which you can get in the larger plant.

Mr. INDRITZ. But even in the larger plant isn't there room for research as to the costs, and couldn't that too be considered a pilot plant, even though it is in a larger and more costly stage?

Mr. AANDAHL. I presume you get into varying stages of the process where you go from the smaller pilot plant to the larger, and ultimately to what you would call a demonstration plant, and they all tie together.

Mr. INDRITZ. Has the Department recommended to Congress any legislation to broaden the scope of the present act?

Mr. AANDAHL. Up to the present time we have not. As you know, several bills have been introduced, apparently intended to authorize the Department to construct demonstration plants. In reporting on those bills we have indicated that we think that there are more imporant functions for the Office of Saline Water to perform at the present time than the construction of a demonstration plant. We have spoken specifically about initial pilot plants or some of the processes that look very good, and more advanced pilot plants for some of the processes that we now have under pilot plant testing. But we feel it is too early even to consider the idea of a very large demonstration plant.

In reporting on the bills before Congress, we have indicated that.

Mr. JONES. Mr. Secretary, at that point would not your pilot plant satisfy the same inquiries as would a larger plant?

Mr. AANDAHL. They would go a long ways toward doing that. There are some bits of information which can come from a large demonstration plant that you do not get from a pilot plant, but in reporting to the Congress both by draft report and by oral report we have indicated to the Congress that if they wished to give additional impetus to the saline water program and want to add some legislation to what we now have, it should be in the nature of authorizing us to go a little further with the advanced pilot plant work.

I might say that both the time and money limitations of our present statutes are such that we could not go very far in the large pilot plant work that is looming before us so soon.

Mr. INDRITZ. Those bills would have provided additional authorization and additional moneys, would they not?

Mr. AANDAHL. Yes. And if they are drafted in such a way that they deal with the pilot plant phase of the work rather than specifically designate a large demonstration plant, they would be helpful to the program.

Mr. INDRITZ. At the present time are your reports adverse to those bills?

Mr. AANDAHL. No. Our report is adverse to the idea of authorizing a demonstration plant, but not adverse to the idea of giving further impetus to pilot plant work.

Mr. INDRITZ. If the word "demonstration" were changed to read "pilot plants on a large scale capable of producing up to 1 million or 2 million gallons of water per day for the purposes of research to determine whether the plants could be operated economically and what further improvements could be made," would you then favor those bills?

Mr. AANDAHL. Bills of that kind would be helpful. I think they should not be limited to 1 or 2 plants. The bills that are on the Senate side where we appeared before the committee, are bills which embody a $10 million authorization. With that amount of money being authorized I think it should be available for more than 1 or 2 plants,

and we could probably take a half a dozen large-scale pilot plants with that amount of money.

Mr. INDRITZ. Is it your belief, Mr. Secretary, that the program is now advancing as rapidly as is possible and proper?

Mr. AANDAHL. You have asked two questions. You asked the question of possible and you asked the question of proper. There is not any question but what it is possible to move faster. If you have more money and a bigger program and make a crash program, you can go much faster.

The other question is, is it proper to go faster? We in the Department of the Interior have been thinking in terms of a gradually accelerated program. I think we can be much more constructive and much more productive in the amount of money we spend if we have a gradually accelerated program.

If there is an occasion for a crash program, why, it can be handled that way, but unless there is extreme urgency I think it is much better to have a program that you build more gradually by experience; and our program is working in that direction.

I think we have now reached a point where it can be stepped up quite appreciably in the next few years.

Mr. INDRITZ. I asked the question because 3 months ago, on January 13, 1958, when Secretary Seaton appeared before the House Appropriations Committee, he was asked that question, and Secretary Seaton answered, that the program was advancing "as efficiently and properly as possible" (Hearings on Department of the Interior and Related Agencies Appropriations for 1959, 85th Cong., 2d sess., p. 14).

Mr. AANDAHL. Yes. If you would tie the emphasis to the word "proper," which I presume the Secretary had in mind, that is about the way my feeling is. I think we are moving into it at a reasonable rate, and one that gives us an opportunity to have our feet on the ground and know what we are doing.

Mr. INDRITZ. The subcommittee was concerned because in the same hearings the testimony that was presented to the Appropriations Committee indicated that a number of projects which were ready for pilot-plant stage were being cut back, or postponed, or were not accelerated. These included solar distillation and reverse-osmosis process; the freezing process was being limited to preliminary engineering; the solvent-extraction work was not going forward; and the use of nuclear energy was still then in a stage of exploratory calculations. Other processes and needs apparently were being, as was stated in the hearings, postponed, and, therefore, I would like to ask whether a change seems to have taken place in the last 2 or 3 months, as to whether the Department is proceeding promptly and as rapidly as possible.

Mr. AANDAHL. I think probably an outline of the budget estimates that were submitted by the executive branch, and the appropriations that are allowed by the Congress, will throw some light on that.

For fiscal 1953, the executive branch asked for $400,000. The appropriation was $175,000.

In 1954 we asked for $400,000 and were granted $400.000.

In 1955 we asked for $400,000 and were granted $400,000.

In 1956 we asked for $600,000 and were granted $600,000.

In 1957 we asked for $600,000 and were granted $550,000.

For fiscal 1958 we asked for $1,159,000. That was almost the annual pro rata share of the remainder of the $10 million under our appropriation. It was not quite the annual pro rata share because we felt during the later years as we got more processes in pilot-plant testing that we would need just a little bit more in the following years, but we were almost up to the annual pro rata share. However, Congress allowed us $725,000 out of the $1,159,000.

Now, in 1959, while we had $725,000 in the previous year, we asked for $825,000.

I want to call your attention to the fact that at the time the executive branch was preparing the budget for 1959, we were struggling under rather tight budget conditions in the executive branch. We had the experience of the Congress in the previous year holding us pretty tight. We had some sputniks in the air and there was quite a clamor for a step-up in defense activities. But under the tight budget conditions we had 6 or 7 months ago, when the 1959 budget was being prepared in the executive branch, we submitted a $100,000 increase, or we asked for $825,000.

When the House Appropriations Committee acted on it, they allowed us $785,000. However, in the last few months the nationwide economic conditions are a little bit different than they were 6 months ago, and there is quite a little activity and thought given to increased Federal activity. If that is going to take place, why, certainly we can spend a little more money to advantage in the saline-water program.

Just during the past week the Secretary announced on the recommendation of the advisory committee, which met March 25 over in the Department of the Interior with us, that he is now going to ask for a supplemental appropriation which would bring the 1959 appropriation up to the annual pro rata share of the $10 million for the remaining years.

That is our thinking at the present time.

Mr. KNOX. Will the gentleman yield?

Mr. INDRITZ. Yes, sir.

Mr. KNOX. At that point, relative to the position of the Department, it is apparent that the Department has been on top of his problem, but by virtue of the fact that Congress has not given all of the money that the Department has requested it has somewhat delayed the Department's program as far as saline water is concerned.

Mr. AANDAHL. That was quite an appreciable factor as far as fiscal 1958 is concerned.

Mr. INDRITZ. Mr. Secretary, in response to the chairman's request for information concerning the need for going forward with an adequate pilot-plant program in the processes which are now ready for them, Assistant Secretary Beasley, of the Department of the Interior, in his letter of April 2, 1958, indicated there are several processes which are in the proper stage for active pilot-plant work. He mentioned 3, or possibly 4, kinds of distillation processes, 3 types of membrane processes, and 1 freeze evaporation process, possibly 1 solvent-extraction process, and the design of a nuclear heat distillation combination, as being the types of processes ready for such pilot-plant work, and indicated that the estimate of the costs for such activity would be in the neighborhood of $1.4 million to $1.8 million for the

next year, and $3¾ million to $4½ million for the following year.

How does that compare with the $530,000 the Secretary just indicated he would request as a supplemental appropriation?

Mr. AANDAHL. Those figures, as I understand it, are based on placing all of those processes in pilot-plant operation simultaneously. At the present time we have two processes under pilot-plant testing at Harbor Island, N. C. They are two of the distillation processes. With the additional amount of money we have asked for in the supplemental we could put several more under pilot-plant testing. I have not checked specifically to know exactly how many we could place, or which we would select if we were going to make a selection, but if the money we have asked for is available we will pick out several—as many as we can of the additional processes which are most promising and that are most complete in their preparation for pilot-plant testing, and put them in pilot-plant testing.

Again, if you want a faster program and more money could be made available it will go faster, but I think we will be making excellent progress if we get the amount of money that has been asked for in the supplemental and proceed on that basis. We will have several of these additional processes under pilot-plant testing.

We will also look forward to placing at least one of the distillation processes which is in initial pilot-plant testing at Harbor Island under larger pilot-plant testing quite soon.

Mr. INDRITZ. In his opening statement the chairman referred to the conference report of the House and Senate conferees on the 1955 amendments in which it was stated that both national and international conditions required that the program be expedited, that there was an imperative need for speeding up the objectives of this program, and that the program cannot be allowed to drift along without producing concrete results.

In the light of that objective as stated by Congress in 1955, at a time when the Office of Saline water was still engaged in its basic research and just beginning to get into the pilot-plant operation, in view of the fact that you have these many processes ready for pilot-plant stage, is it not the obligation of the Department to recommend to the Congress the appropriation of sufficient moneys to enable the Department to put all of the processes into pilot-plant work so as to achieve this imperative need for speeding the objectives of the program, and would it not therefore seem that the $530,000 supplemental appropriation is only a portion of that need?

Mr. AANDAHL. The statement of urgency expressed by the committee in the language that you have just read was associated with an authorization of $10 million. It was the judgment of Congress at that time that $10 million would take care of that urgency. The appropriation that we are asking for——

Mr. JONES. That was over a 13-year period, too.

Mr. AANDAHL. Yes. The appropriation we are asking for is the annual prorata share of the $10 million which is the Congress's measure of what is required to meet the urgency that they gave expression to.

Mr. INDRITZ. Yet in the basic act——

Mr. JONES. Just a minute. I am more interested in the research, because from what I have been able to observe and read, we do not

have any known processes by which we are sure we can produce converted water at a reasonable cost.

What about the research program?

Mr. AANDAHL. Mr. Chairman, it is very important to continue the research program. I would say that that is the first rung in the ladder of our program—to continue research. However, research has gone further with some processes that are sufficiently promising so that they should be put in pilot-plant testing. We have two of them in pilot-plant testing now, and we have one which was placed under pilot-plant testing several years ago. We have three which we are moving quite a little ways on pilot-plant testing and they should go into that stage.

When you hear the report of our technical people of what is being done both in research and in the processes and the explanation of the processes which have reached the stage where they should go into pilot-plant testing, you will understand what is involved, I am sure. But both are important.

Mr. JONES. It seems to me the whole proposition is divided into two sections, or into two general objectives. No. 1 is the research.

Mr. AANDAHL. That is correct.

Mr. JONES. No. 2 is the development of the pilot-plant work in the perfection of the various processes which are developed in the laboratory. If we are going into pilot plants and are going to neglect research, I do not think we will make great strides, because it seems to me that that is the heart of the whole program.

Mr. AANDAHL. Our appropriation requests have always been based on the combination of research and pilot-plant work in the more recent years when we reached the period where we can do some pilot-plant work. As we appear before the Appropriations Committee, certain portions of money are designated for research and certain portions are designated for pilot-plant work.

Mr. JONES. I do not see any general optimism on the part of the technicians or any utterances coming from them that would disclose great optimism with regard to any of the known processes yet proposed: and to the fact that they will reduce the price to where it can serve a general useful purpose for producing water at a rate that industry and the domestic users can afford to pay.

Mr. AANDAHL. I think that I detect fairly substantial indications of progress in reducing the price. I am not going to attempt to go beyond that statement because I want our technical people to present that information to you.

Mr. JONES. The experts are reluctant, just as you are, in talking about the cost estimates, as you notice when you go through reports, to give cost estimates because there are so many unknown factors involved in the figures for the cost of producing water that they do not want to make these guesses. They feel that further research is necessary for determining the cost figures.

Mr. AANDAHL. That is entirely correct. When you take a process that looks promising in the laboratory and looks promising on paper and put it into pilot-plant operation, you know that there are a number of uncertainties there. Technical people are just reluctant to try to be too specific about the exact price at which the water can be converted.

On the other hand, as I view the overall program, I find many reasons to be optimistic about what is being accomplished and what can be done very soon in the price of converting water.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. Mr. Secretary, the act of 1952 provided that the Secretary of the Interior shall make reports to the President and the Congress at the beginning of each regular session of Congress and that such reports should include suitable recommendations for further legislation. In the light of the progress which has been made from the research to the pilot-plant stage, do you think that the Department should recommend to Congress the modification of the statute which now requires that the expenditures should be scheduled in equal annual amounts within the limits of the authorization?

Mr. AANDAHL. No, I do not think there should be any modification of that. As long as our program is set up by that authorizing legislation, I think that that is an advisable standard of progress to follow.

I also think it is quite proper in the light of what we are doing in our program if we get an appropriation equal to the annual pro rata share of the $10 million—I think we are all right for a year or so. When we have a little more specific information about what these pilot plants are going to show, then we may want to recommend some additional legislation. But for this session of Congress I think we are in very good shape, and we have a proper program before us with the legislation which we have.

Mr. INDRITZ. In view of the statement of urgency which is the general objective indicated by Congress, and in view of the fact that so many of the processes which are ready for pilot-plant stage are being postponed, as indicated by the presentation made recently before the House Appropriations Committee, and in view of the fact that Assistant Secretary Beasley indicated that the amounts which would be needed to put these processes under pilot-plant stage testing would be from $4½ million to $6 million in the next 2 years, and in view of the fact that you have only about $6 million left for your entire authorization, is it not desirable to bring these facts to the attention of the Congress and recommend the amendment of the legislation so that you can proceed in conformity with the basic objective of Congress as expressed in the conference report?

Mr. AANDAHL. We are proceeding in line with the basic objective of Congress as expressed in the conference report and as written into the law. I would feel that our office of saline water would be deficient in its responsibility if it did not have somewhat of a surplus at this stage of the game, of research dealing with processes that can be put into pilot-plant testing. I think we should have a reserve. We should have more processes than we are actually going to put into pilot-plant testing, and we should be in a position where we can take out several of the best or several of the most promising of those that have reached the technical review stage where they can go into pilot-plant testing.

Mr. JONES. What is your unexpended balance, Mr. Secretary?

Mr. AANDAHL. A little over $6 million. I do not have the tabulation here.

Mr. INDRITZ. $6,775,000.

Mr. AANDAHL. Yes.

Mr. JONES. With that figure then you are way behind the calendar, are you not?

Mr. AANDAHL. No. I think we should understand that in the initial stages of a research program of this kind the study that is made by the technicians and the scientific research that is made does not cost nearly as much as the pilot-plant operation that follows.

Mr. JONES. I understand that.

Mr. AANDAHL. I think we are moving into it in just about the right proportions.

Mr. KNOX. May I ask a question?

Mr. JONES. Yes, sir, Mr. Knox.

Mr. KNOX. I had not intended, Mr. Secretary, to interrogate you at this particular time, but there have been some questions raised relative to research.

How many of our State universities now are cooperating with the Interior Department in a research program?

Mr. AANDAHL. We have submitted to the commitee a list of all of the contracts that we have let here. Do you have them broken down on that basis, Mr. Jenkins?

Mr. JENKINS. Not broken down on that basis. They are listed here, but we could break them down for the record in that way.

Mr. KNOX. It is not necessary to break them down. I was wondering about the approximate number of contracts you had with the universities or private corporations.

Mr. JENKINS. There have been, I would estimate, about half of the contracts with universities. Perhaps a little more than half. The others have been with individuals and with industrial organizations and with research institutes.

Mr. KNOX. And following the research work that is being done by the universities, then from that you determine the type of operations which will be put in as a pilot-plant operation?

Mr. JENKINS. The way that works, Congressman Knox, is when we have a process or a given factor in a process being developed in the research phase, whether it be in a university or a research institution, or even in an industrial organization, evaluations are made as we move along, and when the time comes for an engineering development—call it small pilot plant if you wish—the universities, if they are conducting the work, in general do not wish to get into the pilot plant developmental phases. They prefer to remain in research because that is a part of their academic activity.

Mr. KNOX. On page 2 of your report, Mr. Secretary, you mentioned the fact that the initial target for converting saline water for irrigation use was set at about $40 an acre-foot. Then you also state on page 3 that there are some industrial uses of converted sea water being made in California by the Pacific Gas & Electric Co., which is converting sea water for one of its boilers at about $650 an acre-foot, or approximately $2 per thousand gallons. Of course, that is $610 higher cost per acre-foot than what was the goal when Congress initiated this program.

Now I ask if the Pacific Gas & Electric Co. received any information from the Department of the Interior from the research work that had been done at the universities before they set up this operation for the conversion of sea water for one of their boilers at their respective plants?

Mr. JENKINS. Through the annual reports that are prepared each year, which summarize all of the work being done, I believe that the Pacific Gas & Electric Co. received this information. I would have to check the record on that.

Mr. AANDAHL. I think it is correct to say, though, that $2 a thousand gallons for distillation processes is a price that has been possible for some little time. I do not think we are to associate very much credit to the Office of Saline Water for the particular thing that the Pacific Gas & Electric Co. did.

There is another fact I want to call your attention to, and that is where we are talking about $40 an acre-foot for irrigation water. The work that we have done so far, that is thought of most closely in terms of irrigation water, has been the desalting of brackish water rather than sea water. As you go down from 4,000 parts per million or 500 parts per million making brackish water suitable for irrigation, it can be done at appreciably less cost than taking the larger amounts of salt out of sea water. So there is the prospect of two different types of water being used in these figures shown here.

The Pacific Gas & Electric Co. have their plant located near the sea, and as I understand it they are using sea water by a rather well known and long-time-used conventional method of distillation, with a few refinements in it. They may have picked up a little information from the Office of Saline Water, but we do not want to be in the position of trying to claim very much credit for what the Pacific Gas & Electric Co. did. That is a private enterprise venture in line with what industry has been doing for quite a little while.

Mr. KNOX. The reason why I raised the question is to determine how long this plant has been in operation by the Pacific Gas & Electric Co.

Mr. AANDAHL. It was built quite recently. Does anyone have the year in mind?

Mr. JENKINS. I believe it was built in 1955 and it was designed in 1952 or 1953, when this program was being started.

Mr. KNOX. Then there would not be too much opportunity for them to improve on their operations through the knowledge they had obtained from research that has been going on through the universities?

Mr. JENKINS Not at that time.

Mr. KNOX. There was insufficient time for them to have that opportunity. I was interested in the question and I certainly congratulate the Pacific Gas & Electric Co. for taking the step in that direction to endeavor to try to bring about more water for domestic use and for industrial use, and so on, as we go down the line.

Mr. AANDAHL. I might say, Mr. Congressman, that the two distillation processes we have in pilot-plant testing at Harbor Island at the present time indicate that water can be produced by those processes at around $1 per thousand gallons, or perhaps a little less. That shows quite an encouraging advance in the process of sea-water conversion.

Mr. KNOX. Through your pilot-plant operations is it the intent, or is it the policy, and has it been in operation where you have expanded on the pilot-plant operations as additional information has been made available through research at the universities?

Mr. AANDAHL. No. The only pilot plants of any appreciable size are the three I have referred to. One is the ionic process tested by a portable unit in Arizona for 6 or 7 months, and then in South Dakota for a little shorter period, and is now in the Bureau of Reclamation laboratories in Denver undergoing periodic checks. Its improvement to a large degree will be associated with the perfection of the membranes that are used in the equipment. The ionics people and other manufacturers and foreign interests over in the Netherlands during the last year or two have been making considerable progress in perfecting membranes that can be used in equipment of that kind.

The other two processes are those currently at Harbor Island, which have been in operation since about the first of the year, or shortly thereafter, and they will need considerable additional pilot-plant operation there before we can make any determination as to what additional pilot-plant work can be done with the processes.

Mr. KNOX. That is all, Mr. Chairman.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. Mr. Secretary, in the presentation by the Department before the Senate Subcommittee on Appropriations on March 26, approximately 3 weeks ago, it was stated that, even with the $825,000 then requested for the program during fiscal year 1959, it will be necessary to continue some of the promising developments at a very minimum rate, and to defer important research developments on others, and the Department's presentation further stated:

> Thus, unlike construction which can be deferred, if it is necessary to postpone for long a promising line of research and developmental work, it becomes difficult or impossible to reactivate that work at a later date because of the inability to obtain the scientific personnel necessary.

In the light of that statement and in the light of Assistant Secretary Beasley's statement that $4½ million to $6 million are necessary in the next 2 years in order to put those processes which are ready for pilot-plant testing into that form of research, do you believe that the Department has been moving forward as rapidly as is compatible with the urgency expressed by Congress?

Mr. AANDAHL. I think it is very fortunate that conditions are such that we can ask for the supplement that is now in the process of being submitted. I think, with that amount of money available, we will be able to make proper progress during the next fiscal year.

Mr. INDRITZ. With that supplemental, will you be able to put all of the processes that are ready for pilot-plant testing to that form of research?

Mr. AANDAHL. No. That is correct, but we will be able to pick out those that are most promising. I am not sure that it is a proper program to put everything in pilot-plant testing that an analysis indicates shows promise. I think it is probably a more proper program to pick out the most promising and work with those, first, and see what you can do with them.

Mr. INDRITZ. Is it not true that there are different kinds of processes suitable for different kinds of problems in different geographical areas and on different kinds of waters?

Mr. AANDAHL. That is correct, and you can pick out several that will have a fairly wide range to which they can be applied.

Mr. JONES. Is that selection recommended by the Advisory Committee, Mr. Secretary?

Mr. AANDAHL. I do not think that the Advisory Committee attempted to get very much into detail on the selection of processes.

Mr. JENKINS. Might I add there, Mr. Chairman, in your letter of February 24 the question was raised in this connection; that the information was requested concerning projects which are sufficiently advanced for pilot-plant testing, or larger scale testing if additional funds for such testing were available. Then when the complete list of all pilot plants that might be undertaken—if there were to be a crash program is the way we interpreted this—if that was prepared there was included in the list all projects that were feasible for pilot plants; not confining it in any way to the pro rata share at the present time. This question had to do with what could be done if, as I interpreted it, there were a crash program.

Mr. KNOX. On that point, is it not true not every idea that comes out of research is necessary to be put into development. It seemed to me that anything that looked unpromising you would, certainly, have every right to reject the report which came from the research laboratory relative to this particular operation. Surely, you do not put everything into development, do you, that comes from the research plants?

Mr. AANDAHL. No, and these processes that we have been talking about for the last few minutes are processes all of which show some degree of promise, but I do not think it would be the proper procedure to put every one of them into the pilot-plant testing. I think we should be selective and we should pick out those that are most promising and those that have a range of application.

You can pick out a few that have a range of application. If they, under pilot-plant testing, do what you expect them to do, there will be one that will be suitable for this kind of water under this kind of circumstances, and another one suitable for another kind of water. There may be two that will take care of the first kind of water. But if we pick out the one that is the most promising and develop that, and it is satisfactory, maybe that is the most we should do for the moment in a proper program.

Mr. KNOX. I agree, Mr. Secretary; the objective is certainly sound and to the best interests of the program for use and, also, the development program through your pilot-plant operations.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. Mr. Secretary, do you think that there should be more research work done with the aid of Federal laboratories?

Mr. AANDAHL. Well, as indicated by your question, there are two methods of research that can be followed. One is to build up a sizable Federal laboratory and a staff to work with them. The other method is to use, quite extensively, contracts and grants with entities other than the Federal Government.

Mr. JONES. Is that not the cheapest?

Mr. AANDAHL. I am inclined to think that we can have a very broad and a very satisfactory range of accomplishment by that process. I do not want to discredit the other, because it is a valuable method, also, under certain circumstances, but I think we have been making very good progress with the saline-water program under the type of approach we are following, and we have gotten pretty deeply into it, and it is working quite well, and I think it would be undesirable to change it.

Mr. INDRITZ. Are there not instances in which the Federal laboratories, if the limitation on the expenditure of funds for the work by Federal laboratories were modified, would aid in confirming or checking reported results, or giving evaluations clearly without bias?

Mr. AANDAHL. Insofar as the money limitation is concerned, we, under present statute, are authorized to spend more money at the present time in Federal laboratories than we have found it advisable to spend. We are not spending the amount that is permitted under our present statute in Federal laboratories. Wherever there is occasion to use a Federal laboratory to advantage, why, we do so, but we do not have statutory limits on the extent to which we are doing it at the present time.

We have a limitation, but we are operating well below that limitation.

Mr. INDRITZ. You are not utilizing Federal laboratories very much, then?

Mr. AANDAHL. Only to a very limited degree.

Mr. JONES. What office are they being used for now, Mr. Secretary?

Mr. AANDAHL. We are using the Bureau of Reclamation Laboratory at Denver and we are using the Bureau of Standards Laboratory. The total expenditure through 1957 was $55,000.

Mr. JONES. How does the Laboratory get the accumulated analysis and evidence?

Mr. AANDAHL. I will defer that question to Mr. Jenkins.

Mr. JONES. I will defer that until later on, then, because you will be a witness, Mr. Jenkins. The Secretary is a quite busy fellow and we do not want him to have to come back. We will confine our questions to the Secretary and then defer the other questions to the staff till a little later.

Mr. INDRITZ. The Advisory Committee on Saline Water Conversion was established back in 1952, was it not?

Mr. AANDAHL. Yes.

Mr. INDRITZ. How many meetings has it held since that time?

Mr. AANDAHL. There have been three meetings.

Mr. INDRITZ. According to the information which has been furnished to us, there was a meeting in December 1952 and one in April 1954, and the most recent one was in March 1958. Is there any particular reason why the Committee was not convened for the last 4 years, until just 3 weeks ago?

Mr. AANDAHL. As you know, this committee is made up of members from clear across the United States. There are several from the Pacific coast. We are constantly in correspondence with the members of the committee. We send them our periodical reports. From time to time we ask them questions on policy matters which we are considering. We take care of as much of our contact with them as we can by correspondence.

From time to time it seems advisable to have a conference such as we had in 1954 and such as we had on the 25th of March. I think we have been using the Advisory Committee to good advantage and have called them in about as frequently as there has been specific occasion to do so.

Mr. INDRITZ. In their recommendations of May 1954 the committee suggested that there be one group meeting per year unless the Sec-

retary desires additional meetings for consideration of special problems. Is the fact that the Secretary did not call them together for 4 years an indication that he did not think they would be very useful in the Office of Saline Water program?

Mr. AANDAHL. No, not at all. In fact it is quite difficult to get them together. This meeting we had in March was first called for what time, Mr. Jenkins?

Mr. JENKINS. January 14.

Mr. AANDAHL. And we have been in correspondence several months in advance of that in trying to get a date at which they could be present. Even when we had our meeting in March there were several alternates sent for the principals. It is not too easy to bring a group of men of that kind together and get them to devote a day or two of their time away from home to the program. As you appreciate, they are operating without compensation. They do have their expenses paid when they come to the meetings we have.

Mr. INDRITZ. About 3 weeks ago on March 27 the Under Secretary of the Interior recommended to Congress proposed legislation to establish a desalinization plant on the Virgin Islands. This proposal would have provided for distillation facilities for the production of the water, but apparently there was no provision incorporated in the bill drafted by the Department to perform any of the research functions in connection with the objectives of the Office of Saline Water. Why was not that proposal for a distillation plant on the Virgin Islands coordinated with the Office of Saline Water's objectives?

Mr. AANDAHL. It would have been most improper to do so.

Mr. JONES. Mr. Secretary, let us stay with the proposition which is within the scope of the inquiry, namely, as to research and development works that are taking place. It is much better for the Secretary to talk about what they are doing than what they failed to do about some particular individual isolated instance. So I think it would be more proper if we would confine ourselves to the general subject at this time.

Mr. INDRITZ. Mr. Secretary, do you think there could be increased progress in the Office of Saline Water's research program if there were cooperation with States and localities near the sea, or having brackish water?

Mr. AANDAHL. Yes. And we are constantly attempting to cooperate with States and municipalities and with research institutes and with industry, and we are specifically authorized to do that by the legislation under which we are operating.

Mr. INDRITZ. Have there been any such agreements or projects?

Mr. AANDAHL. You are asking about a cooperative program with a State or a municipality?

Mr. INDRITZ. Yes, sir.

Mr. AANDAHL. Do we have anything like that?

Mr. JENKINS. Mr. Chairman, we have been negotiating with the State of California for a cooperative program. Those negotiations are pretty well along. We have not quite reached agreement on the terms but we have an indication from the State engineer that he is in general agreement with the idea and with the terms that were negotiated. I had a meeting with him during the recent hearings in the Senate, in which he said there were a few changes he wished to

make in the plans that had been negotiated, and he would be sending that forward. He has done so.

That letter came in just this past week and we have been so busy getting ready for this work that we have not had an opportunity to see what his changes are.

Mr. AANDAHL. We are very anxious to enter into cooperative agreements of that kind whenever we find a State or municipality which has something to contribute and is ready to work cooperatively with us and be helpful in the program.

Mr. INDRITZ. Mr. Secretary, in connection with the work that the Department is doing on saline water does it keep in mind that the conversion of salt water is not a substitute for the general conservation of fresh water, and that it is important to help relieve shortages in those areas which have them due to pollution, or inadequate distribution systems, to provide better storage facilities and, in general, to have less waste of our natural fresh water resources?

Mr. AANDAHL. As you know, the Department of the Interior is sometimes referred to as the custodian of the Nation's natural resources. We are very much interested in measuring and knowing and understanding more about the water resources of the country. Particularly in the Western States the Bureau of Reclamation has a very expansive construction program in which it is building dams and creating reservoirs for the purpose of conserving and more wisely using the water resources of our country. We are very active in activities of that kind.

Mr. INDRITZ. Do you believe that the Office of Saline Water is sufficiently staffed to move forward with expedition on the research program? Does it need more personnel?

Mr. AANDAHL. The Office of Saline Water is getting along reasonably well with the amount of work it has. If we get additional appropriations and have some additional pilot plants to operate and get busy with some additional research, why, we will need some more people; but the staff we hope to keep proportionate to the work we are doing.

Mr. INDRITZ. Why has not the Department had any foreign cooperative contracts or projects?

Mr. AANDAHL. Our experience has been that the Appropriations Committee that approves the use of the money we have to spend has looked with considerable question on the spending of saline water money abroad. When the 1955 amendment to the authorization act was enacted there was a provision in there that authorizes the spending of a portion of the money abroad and in cooperative contracts with research ventures in other countries.

On the other hand, as we appeared before the Appropriations Committee we have noticed there has been considerable reluctance to approve the use of money very extensively for that type of purpose.

Just preceding the enactment of the amendment in 1955 the Office of Saline Water had gotten pretty well along in negotiating and having ready a contract for cooperative participation with a group in the Netherlands on the ionic process, but when the Director came to me to ask about approving that contract in the light of the opinions that had been expressed by the Appropriations Committee I indicated that I didn't think we should do it until we had it specifically authorized

in the legislation; and after the amendment was enacted and we got to a point where we felt that both by the authorization and by the exchanges that had taken place in the Appropriations Committee we could have spent the few dollars that were involved in that cooperative contract, the work abroad had advanced to a point where they no longer needed our cooperation. So we did not become a part of that joint international venture which was underway in the Netherlands.[1]

Mr. INDRITZ. As we read the testimony and comments of the Congressmen at the appropriation hearings of January 31, 1955, that you referred to, the discussion concerned only the question of travel abroad, not the question of cooperation with foreign agencies. And it related even there only to travel where there had not been preliminary inquiry by correspondence.

In fact, the chairman of the subcommittee indicated that he approved travel abroad if there had first been inquiry made as to the adequacy—the need for the travel.[2]

Now, in light of that, it would seem, therefore, that the failure to move forward with the agreement with the Netherlands organization may have cost the United States the opportunity to participate in their research.

Could you tell the subcommittee as to what were some of the disadvantages to the United States as a result of our not being party to that contract?

Mr. AANDAHL. We have an opportunity to profit from the accomplishments that were made in that experimental work. I think probably I should ask Mr. Jenkins to again give you some of the latest information in connection with our contact with the Dutch.

Mr. JONES. Mr. Secretary, we will defer that because we want to complete your testimony.

Mr. AANDAHL. I would say generally it would would have been desirable to have been a party to that contract. And we wanted to be in there. But our contacts with the Appropriations Committee were such that we were just hesitant to move ahead.

On the other hand, insofar as the experimental work was successful and additional information was brought out as a result of it and progress was made, we are not excluded from benefiting by those accomplishments. We are in the process of contacting the Dutch and becoming better and better informed on what they are doing and I think are going to be in a position where we can take advantage of the conversion units that they are building as a result of their experimental work.

Mr. INDRITZ. Mr. Secretary, on April 11, 1958, Secretary Seaton issued a press release concerning the recommendations of the Saline

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[1] This international venture in the Netherlands is a research project in electrodialysis jointly sponsored by Australia, France, the Netherlands, South Africa, and the United Kingdom. Other contributing countries are Greece, Israel, and Pakistan. The work is being carried out at the laboratories of the Central Technical Institute of the Organization for Applied Scientific Research in the Netherlands, generally referred to simply as TNO (Toegepast Natuurwetenschappelijk Onderzoek). TNO is not a governmental organization, although it is partially supported by the Netherlands Government. It operates under a group composed of 50 percent representation of scientists and 50 percent industrial and economic interests.

The correspondence and actions concerning OSW's proposed cooperation in this international research project accompanied the Department's letter to the subcommittee chairman dated April 8, 1958, and are available in the subcommittee files.

[2] Pp. 39–42, hearings before subcommittee of Committee on Appropriations, House of Representatives, 84th Cong., 1st sess., on Interior Department and related agencies appropriations for 1956 fiscal year.

Water Conversion Advisory Committee in which he endorsed, apparently, recommendation No. 1. I wonder if you could tell us what action will probably be taken by the Department on the other 10 recommendations.

Mr. AANDAHL. I think I would prefer not to attempt to specifically answer that question. I would answer it in a general way. I will answer it to the effect that when the Advisory Committee met with us I served as Chairman and was with the Committee the entire day, and not only did we get the specific 11-point recommendation, but we exchanged ideas during the day on matters that were involved, and I would say generally that I feel that the recommendations are all sound and substantial and will help us to chart our course in the Office of Saline Water.

Just specifically what we are going to do in each instance I am not prepared to answer at the moment.

(The press release of April 11, 1958 is as follows:)

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
INFORMATION SERVICE,
*April 11, 1958.*

SECRETARY SEATON TO REQUEST FUNDS TO ACCELERATE THE SALINE WATER CONVERSION PROGRAM

Secretary of the Interior Fred A. Seaton today released recommendations of the Saline Water Conversion Advisory Committee and announced he will submit to the Bureau of the Budget a request for an additional $530,000 in the appropriation for the saline water program. If approved, the request would increase the saline water program figure from $825,000 to $1,355,000 for fiscal year 1959.

"The request for the increase in appropriations," the Secretary said, "is based on the recommendations submitted to me by the Advisory Committee after their meeting at the Department of the Interior on March 25."

"The Committee is composed," the Secretary continued, "of some of the outstanding scientists in the country, particularly in the field of saline water conversion."

Members of the Committee who attended the meeting were: Prof. Everett Howe, representing Dr. Robert G. Sproul, president, University of California; Mr. Sheppard Powell, consulting engineer, Baltimore, Md.; Prof. Jack McKee, representing Dr. Lee A. DuBridge, president, California Institute of Technology; Dr. Louis Koenig, Koenig-Research, San Antonio, Tex.; Dr. Ralph A. Morgan, representing Dr. Frederick L. Hovde, president, Purdue University; and George Humphrey, president, University of Wyoming.

Secretary Seaton said the Committee reviewed the progress achieved thus far under the program, evaluated the present activities, future requirements, and existing legislation, then drew up and submitted the following comments and recommendations:

1. Program should be accelerated through stepped-up appropriations making full use of the existing authorization.
2. Existing authorization should be spent for research and initial pilot plant development.
3. Large pilot plants should come from additional authorization and earmarked appropriations which are recommended.
4. The duration of the saline water program should be extended beyond the existing authorization.
5. We should foster foreign contacts and have at least one research project outside the United States which would serve to encourage others.
6. We should encourage cooperating in a foreign demonstration plant in exchange for technological information to the Office of Saline Water regardless of what Government agency would be involved.
7. Availability of a seaside test facility would be extremely desirable.
8. Basic and exploratory research must be continued.

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9. There is an urgency in California which requires definitive conclusions within 6 to 8 years relative to the California water plan.

10. An increased effort should be made to inform the public of the program, progress and responsibilities.

11. Office of Saline Water should be commended for the excellent progress to date with the limited funds available.

"The recommendations of the committee are being closely studied for use in determining saline water conversion policy as the program continues to develop," Secretary Seaton said.

Basis for the determination of the $1,355,000 average amount for fiscal years 1959 to 1963 follows:

| Fiscal year: | *Appropriation* |
|---|---|
| 1953 | $175,000 |
| 1954 | 400,000 |
| 1955 | 400,000 |
| 1956 | 600,000 |
| 1957 | 550,000 |
| 1958 | 725,000 |
| Total, 6 years | 2,850,000 |
| Reserve, final 3 years | 375,000 |
| Total, first 6 years plus final 3 years | 3,225,000 |
| Total authorization | 10,000,000 |
| Available, 1959 to 1963, inclusive | 6,775,000 |
| Average yearly | 1,355,000 |

Mr. JONES. Mr. Romney?

Mr. ROMNEY. Secretary Aandahl, with reference to the opportunity of the Office of Saline Water to enter into a cooperative research project with the Netherlands and other nations in 1955, you mentioned that there was some expression on the part of the Appropriations Committee that perhaps this was not the type of operation the Office of Saline Water should attempt at that time.

Mr. KNOX. Oh, no. Would you yield there? I do not believe that the Appropriations Committee specifically said it was not that type of operation, did they? Let's not——

Mr. ROMNEY. I am sorry, sir. He mentioned that there was some congressional expression of opinion which led the Department to feel that it was not the appropriate time to enter into that arrangement.

Mr. KNOX. Well, now, what I was getting at was I do not think this committee wants to indict another committee of Congress for their actions.

Mr. ROMNEY. No, sir. I was trying to find out, Mr. Knox, from Mr. Aandahl, what these specific expressions of congressional opinion were.

Mr. Indritz has mentioned testimony between the Appropriations Committee and Mr. Jenkins concerning the appropriations for fiscal year 1956. Were there any other expressions of congressional opinion which became the basis for the Department's decision not to pursue the arrangement with the foreign countries at that time?

Mr. AANDAHL. I have not checked the record for some time and I cannot refer to specific statement. But I personally attended the appropriation hearings at that time, and I had both official and unofficial exchanges of opinion with the members of the committee. And until the authorizing legislation was amended so foreign expenditures were specifically authorized and until we had an op-

portunity to exchange information with the Appropriations Committee on the basis of the amended legislation, I felt that it was not advisable to proceed.

As soon as those two things were accomplished, we attempted to proceed. But at that time it was too late to become a part of the cooperative activity.

Mr. ROMNEY. Then the colloquy at the hearings on the appropriations for 1956 to your knowledge forms the basis and the only basis for the decision?

Mr. AANDAHL. No; I am not referring to any specific colloquy that you have on your paper there. I am speaking of the entire record and the experience of our office with the Appropriations Committee.

Mr. JONES. Any further questions?

Mr. ROMNEY. No, sir.

Mr. JONES. Mr. Knox?

Mr. KNOX. I do not believe I have anything further, Mr. Chairman.

Mr. JONES. Mr. Secretary, section 3 of the act of 1952 provides the authority for cooperative enterprises by the Department of Defense and the Secretary of the Interior. Do you know whether any works were executed under a joint agreement?

Mr. AANDAHL. Well, our departments have been in close contact exchanging information and keeping each other apprised of what is being done. I cannot tell you specifically. I would again suggest you ask Mr. Jenkins.

Mr. JONES. Do you know whether on not the Department of Defense has a similar project such as the Department of the Interior?

Mr. AANDAHL. They do not have operations similar to ours, although they are very active in the most practical means of converting water, converting sea water, at places where they need it and no other water is available.

Mr. JONES. Is that the Department of the Navy principally?

Mr. AANDAHL. I do not think that I would want to limit it to any divisions of the Department of Defense. I am not too familiar with what they are doing.

Mr. JONES. Well, the reason I asked is that the whole proposition historically developed for producing usable water aboard ship, and so I thought maybe that passed down.

Mr. AANDAHL. I would think that in the most part they attempt to build the type of conversion process that is time tested and is dependable.

Mr. JONES. Have you had any communication or any contact with any of the agencies of Defense relative to this problem?

Mr. AANDAHL. I have not had any personal contact. The Office of Saline Water has had contacts.

Mr. JONES. And you are not familiar with any projects that are jointly being sponsored by the Saline Water and the Department of Defense?

Mr. AANDAHL. No; there are no such projects.

Mr. JONES. Do you know whether the Department of Defense has any similar projects that they are undertaking at the present time or have had in the past?

Mr. AANDAHL. Mr. Jenkins could answer that question for you. He has had contact with them.

Mr. JONES. Since the passage of Public Law 448 of the 82d Congress?

Mr. JENKINS. Mr. Chairman, I believe that there is a representative of the Department of Defense who is here to testify later, and, of course, he can tell much more than I about their projects.

Mr. JONES. Well, let me ask it in this way: Are the appropriations made to the Department of the Interior diverted over to the Department of Defense in any way to carry out the objectives sought in Public Law 448 and the amendment in 1955?

Mr. JENKINS. No, sir. There has been no such diversion.

Mr. JONES. All right. Now, amendments of Public Law 111 of the 84th Congress provide for cooperative agreements between the Atomic Energy Commission and Civil Defense Administration. Have any cooperative agreements been executed with the Atomic Energy Commission?

Mr. JENKINS. There has not been a written cooperative agreement with the Atomic Energy Commission, but we have cooperated very fully in the past year and a half, on development of combination reactor and conversion processes.

Mr. JONES. Thank you, sir. With the Department of Civil Defense or the Civil Defense Administration?

Mr. JENKINS. There have been a number of meetings with the representatives of the Civil Defense Administration, particularly in light of their possible need for desalting equipment in times of emergency.

Now, the Civil Defense Administration has advised that they are keeping abreast of what we are doing. They would like it if we would develop processes that they could use, but they have no means or financial means of cooperating.

Mr. JONES. Thank you, sir.

Now, Mr. Secretary, do you have any recommendations to make to the committee with respect to amendments to the existing public laws that would assist you in a more orderly prosecution and a more satisfactory pursuit of all the objectives sought under the public laws authorizing the Department of the Interior to carry out research and development on the elimination of salt in water?

Mr. AANDAHL. I have no recommendations other than those that have been forwarded to the Senate committee, which has held hearings on this question. Those recommendations indicated that we did not think that this was the time to build demonstration plants but that if the committee felt that it wanted to give incentive, further incentive, to the work that the legislation be amended so that it relate to authorizing us to build additional pilot plants.

Now, I am inclined to think that after perhaps another year's experience under our present act with some additional pilot plants we may have some specific recommendations to make as far as the future is concerned. But we have not developed our thinking to a point where we want to recommend anything specific other than what I have mentioned.

Mr. JONES. Mr. Secretary, could you satisfy the committee that the contracts now in existence with the universities and private concerns that are carrying out research programs will be carried on continuously without further impairment of reduced appropriation?

I had better change that "reduced appropriation" because that is something you cannot very well control. But what I am getting at is some assurance that there will be a continuing program and that we will not be in and out and having that unsatisfactory situation.

Mr. AANDAHL. Well, you see, during the current fiscal year we are operating with $725,000. If we get the increase that we are requesting in a supplement, it will be sufficient to give us an appreciably enlarged program. That does not mean that every research contract that is in process now will be continued in the future.

Mr. JONES. Yes, Mr. Secretary——

Mr. AANDAHL. We will voluntarily want to make some changes.

Mr. JONES. I understand you are going to have research and development and that in the field of development you are going to use pilot plants. And you can take a pilot plant and you can cut it off and you can cut it on. But with a laboratory where you have got men pursuing a scientific proposition, they cannot run in the laboratory and run an examination one day and quit for the next year. So the research program must be continuous if it is going to produce any results.

Now, are those contracts going to be continued in the field of research with the moneys now on hand, in the Secretary's hands?

Mr. AANDAHL. Well, I presume that your question is pointed at the activities in fiscal 1959.

Mr. JONES. Yes, sir, and the intention of the Department to carry on in 1960, 1961, and 1962.

Mr. AANDAHL. Well, our intention is to pursue an appreciable amount of research, and with the additional moneys that we are asking for we can step up the program quite substantially.

Mr. JONES. Now, for instance, I will give you an example. The University of California at Los Angeles has carried on a research program at a cost of $20,500 by contract for the period from April 16, 1954, to June 30, 1956. Now, is that research project still underway, or is it completed?

Mr. AANDAHL. And many of these contracts——

Mr. JONES. I ask is that still in progress?

Mr. AANDAHL. No. Mr. Jenkins says that that contract is completed.

Mr. JONES. That is completed? All right.

Mr. AANDAHL. Now, many of these contracts that we let are let for the purpose of making investigations in a specific field, and the particular work that is called for under the contract is subject to completion.

Mr. JONES. The contract is subject to completion?

Mr. AANDAHL. Yes. Many of the contracts are subject to completion; that is, they outline a specific amount of work, and when that is completed we have the contribution from them and the type of research that they are doing that we desire. And we put it together as a part of the composite information that we have.

Mr. JONES. Well, that is the point I am getting to now.

Mr. AANDAHL. Yes. Every one of the contracts we have are not intended to be indefinitely continuing contracts.

Mr. JONES. You have one with Cornell that will not be completed until 1959. Now, I would like to have some information as to what

your intentions are with respect to those contracts. Are they going to be fulfilled by the Department of Interior?

Mr. AANDAHL. Well, the thing that we must do is determine whether or not the information that has been supplied and the research that has been done under that contract are sufficient to answer the questions that the Office of Saline Water has in mind. Some of the contracts when they are completed will give those answers.

Mr. JONES. Yes, sir.

Mr. AANDAHL. Others will need to be renewed.

Mr. JONES. Yes, sir.

Mr. AANDAHL. And those that need to be renewed we hope to be in position to renew and we will ask for appropriations.

Mr. JONES. And those that are outstanding to be completed in 1959 or 1960 are to be carried out?

Mr. AANDAHL. Yes.

Mr. JONES. Now, that is what I want to know.

Mr. AANDAHL. Yes.

Mr. JONES. In other words, you are not going to take that money and put it on a pilot plant and abate the research programs that are now under contract?

Mr. AANDAHL. No. I feel that we must continue with a substantial research program.

Mr. JONES. Well, I do too, Mr. Secretary, and that is the reason why I am very interested. To think that we are going to spend all of our effort on a pilot plant and eliminate research seems to me just like backing and filling.

Mr. AANDAHL. Oh, yes; that would be a grave mistake, and we have no intention of doing that. But we have reached the point where we can have some pilot plants as a part of the work that we are doing.

Mr. JENKINS. Mr. Chairman, may I say a word? It may not be quite clear, with such contracts as the one at Cornell and others that we have indicated will be completed in 1959, that the present contract that has been let and the money that has been contracted for run beyond the end of this fiscal year and carry that through the end of this time. So there is no possibility whatsoever of that money being diverted in any way. Even if we were to have no appropriation next year, this contract would continue through 1959 on the money that has been contracted for.

Mr. JONES. Well, Mr. Jenkins, what I had in mind was these long-range plans of research which must be a part of any successful program—to see that they are continued without impairment. And so, since the Secretary has spent most of his time, with Mr. Indritz, talking about pilot plants, I wanted to get my two bits in for research and see that that program is continued, because, as I said earlier, my observation is that research seems to be the part of the program that is dragging its feet.

Mr. Knox?

Mr. KNOX. I have one question relative to your schedule which has been presented to the committee, appendix B. I note that you have some 6 or 7 programs that are designated "not promising." Now, is it the policy of the Interior Department that, where these reports show that the program is not promising from the research work that is being done by the university or private industry, they will now be

dropped and there will be a concerted effort put on to renew contracts where you have them marked "promising"?

Mr. AANDAHL. Yes, that would be the general trend. I presume that occasionally on a process that is marked "not promising" someone may come along with an additional suggestion, a new idea in connection with it which might develop. We may want to take a second look at it. But there would be very limited amounts of work devoted to those processes that are designated as not promising.

Mr. KNOX. And it would be the intent of the Interior Department to press for further research work where there is promising evidence from the reports which have been forthcoming from those institutions?

Mr. AANDAHL. Yes, without any question.

Mr. KNOX. That is all.

Mr. JONES. Thank you very much, Mr. Secretary. This has been a most interesting session, and you have been quite helpful to the committee.

Mr. AANDAHL. We are very glad to meet with you, and I am sure our technical people will give you some valuable information.

Mr. JONES. Thank you, sir.

Now, we will be glad to have you continue to stay with us, Mr. Secretary.

Mr. AANDAHL. I will stay part of the time if I can arrange to do it.

Mr. JONES. Yes, sir.

Mr. AANDAHL. I am very much interested in the further developments of the hearing.

Mr. JONES. Our next witness is Mr. David S. Jenkins, the Director of the Office of Saline Water. Mr. Jenkins, we are delighted to have you, sir.

**STATEMENT OF DAVID S. JENKINS, DIRECTOR, OFFICE OF SALINE WATER; ACCOMPANIED BY DR. W. S. GILLAM, CHIEF, BRANCH OF RESEARCH; J. J. STROBEL, CHIEF, BRANCH OF ENGINEERING; ALLEN CYWIN, ASSISTANT CHIEF, BRANCH OF ENGINEERING; ERNEST SIEVEKA, CHEMICAL ENGINEER, OFFICE OF SALINE WATER; AND PAUL H. GANTT, OFFICE OF SOLICITOR, DEPARTMENT OF THE INTERIOR**

Mr. JENKINS. Thank you, Mr. Chairman and members of the committee.

Ever since the saline water conversion program was begun in 1952, we have invoked precautions and safeguards in the operational procedures for placing Federal aid under this very small Government program which stirs the inventive imagination of so many laymen and that of a few scientists and engineers. Those procedures have been kept to a minimum consistent with statutes and established Government operational policies and requirements.

Although I would, of course, gladly discuss those operational practices if the committee should wish, I note that the committee requests testimony on the broader aspects of progress in saline water conversion, as set forth in your letter of April 1, Mr. Chairman. Therefore, my prepared testimony is devoted largely to several of the inquiries of that letter.

Assistant Secretary Aandahl has discussed the first subject of broad goals of the saline water program. My remarks have to do principally with the committee's inquiry No. 2 regarding progress and No. 3 regarding future plans.

Secretary Aandahl has just said that the program is designed to encourage private research and development in this area. Such encouragement and stimulation has been carried out by the Office of Saline Water, and I believe that the increased private activity, both here and abroad, is in part one measure of progress. Today it appears that there is underway about 3 to 4 times as much non-Federal saline water conversion research as was reported to us in 1953, and events of the past year indicate that this field promises to be competitive in the extreme.

As to the research on processes under the Federal-aid program, I plan, with your permission, Mr. Chairman, to describe briefly some of the more advanced development and later ask three members of the technical staff to present short illustrated descriptions of those activities.

Fresh water is defined broadly as that containing less than about 1,000 parts of dissolved salts per million parts of water. Brackish waters are those containing more than about 1,000 parts, but less than sea water which contains about 35,000 parts per million. In general, processes which remove the water from the salt, such as distillation, are suitably principally for use on sea water, while those which remove the salt from the water, such as the electrical and chemical processes, are more adapted to treatment of brackish waters than to conversion of sea water. There are exceptions to these, however.

In 1952 we recognized that the only commercially available process for converting sea water—distillation—had its limitations and that new low-cost processes would depend on entirely new ideas as well as improvements in distillation. Therefore, we emphasized exploratory research and the need for new approaches.

To stimulate scientific thought, we prepared and sent to several thousand people here and abroad an outline of some 30 processes or phenomena that might be applied to the problem. This resulted in many new ideas for conversion processes which have been studied and evaluated. Through the research work the field has now been narrowed down to five general groups—distillation, solar distillation, freezing, membrane processes, and others including solvent extraction.

These are described briefly as follows:

Vapor compression distillation: An entirely new vapor compression system has been invented by Dr. Kenneth Hickman and developed under this program. A pilot-plant unit built by the Badger Manufacturing Co. is now undergoing extensive field tests at the International Nickel Co. at Harbor Island, N. C. At the conclusion of those tests conducted under contract by the Batelle Institute, the data should permit calculation of reliable conversion costs for this unit, and we should know whether larger sizes should be developed.

Multiple effect distillation: A cycle of 10 or more effects utilizing a vertical long-tube evaporator has been proposed by W. L. Badger. An experimental pilot plant is under test in North Carolina at that same location. Low-cost water by this method depends on scale-free operation, and the present pilot plant must be viewed as a scale test. The process is believed to have very promising possibilities.

Low thermal difference distillation, or single-stage flash evaporation as it is called, is another distillation process which is believed to have considerable merit. An engineering study of this method has recently been completed by the Griscom-Russell Co., and the results appear fairly promising.

The use of membranes in desalting is relatively new and excellent progress in the development of these conversion methods has been made during the past several years.

(1) Electrodialysis: Field pilot-plant tests on one American unit have been completed and the equipment is now being produced commercially by Ionics, Inc. Work now is in progress at the Bureau of Reclamation, Denver Laboratories, on durability and life tests on those membranes and engineering studies on the development of improved equipment and evaluation of available membranes.

(2) Osmionic: This is an entirely new process which has been developed by Dr. George W. Murphy under sponsorship of the program. I might interpolate in my prepared remarks here that Dr. Murphy was given an exploratory contract, almost what we might call a "think" project, in which he was asked to develop something new. He was at the State University of New York at that time.

There was considerable question in our evaluation group as to whether that type of undertaking should be a part of the program. Because of Dr. Murphy's scientific standing and previous work in desalting, we did give him a small project, a contract of about $4,000 to work out some theoretical results and to try to come up with something new. He did—one of the few new things that has grown out of this program.

He then transferred to another university. The process had been advanced to the point that it was out of the university field somewhat, and it was taken to the Southern Research Institute in Birmingham, Ala., where it is now undergoing the engineering and small pilot-plant development.

Dr. Gillam will tell us more about it.

It is somewhat similar to electrodialysis except that it requires no outside electrical current for the desalting. The driving force here is the difference in salinity between a strong brine and the water to be treated. A laboratory model has been tested at Southern Research Institute, and a somewhat larger unit is about completed there.

(3) Reverse osmosis: This process has been shown to be technically feasible and a small laboratory unit has been operated successfully at the University of Florida. Research aimed at improving the durability of the membranes and the very slow flow rates is in process.

Freezing processes: Freezing can produce fresh water from sea water. However, one problem is the development of low-cost methods of separating the ice crystals from the mother liquor. Three processes are currently under development: (1) Zone freezing, as it is called, at Battelle Institute; (2) freeze evaporation, at Carrier Corp.; and (3) direct freezing, by means of butane, at Cornell University. One, and possibly two, of those processes may soon require the fabrication of the pilot-plant units.

Solar Distillation: A number of separate developments have been carried out on simple single-stage solar stills and on one multiple-effect unit. Field pilot-plant tests have recently been initiated by

the Battelle Memorial Institute at their seashore station for testing and further development of these several different types.

Solvent Extraction: Liquid extraction of fresh water from saline water by means of solvents which have an affinity for water but a less affinity for salt is being developed at Texas A. & M. Research Founration. The fabrication of a pilot plant to obtain sufficient data for calculation of costs is the next step.

In addition to process developments, an accessory need arose for some uniformity in calculating costs of converting saline water. Therefore, with the collaboration of outstanding consulting engineering firms and individuals, the Office of Saline Water prepared a cost estimating procedure in an effort to establish some comparability among estimates of existing and proposed processes.

While the procedure is an improvement over no uniformity at all, and is being used rather extensively now, it is, of course, a first approximation and, in addition, is necessarily flexible.

The method requires that some assumptions be made based upon the manufacturer's or researcher's own estimates of capital cost and of water productivity. We are now undertaking a further study which has the purpose of going behind those assumptions as much as possible, and we are continuing to improve and keep current this cost-estimating procedure.

Of greatest importance, perhaps, is the fact that the calculations include all real costs of conversion. All cost factors are considered as reimbursable, all investment money bears full interest, amortization is on the basis of 20 years or less, and there are no special considerations which would reduce the costs. Therefore, any comparison of conversion costs with the cost of fresh-water-supply projects which do not include all real costs must be adjusted to a common base.

Abroad, developments reaching our attention include electrodialysis in the Netherlands, the Union of South Africa, England, and Israel. Improved solar stills are being developed in such countries as Algeria, Morocco, Italy, Spain, and Austrialia. Freezing processes are under development in Israel, Yugoslavia, and France; improvements in distillation have been or are being carried out in England, Sweden, and Switzerland; and improved ion exchange materials are being developed in Algeria, Germany, and a number of other countries.

Costs abroad may have little relationship to those in this country. Water demands and local material and labor costs are all different. Water charges affordable in some regions may be much higher for the smaller quantities of water used. Some of the foreign research is for serving small local needs, while other developments are for large installations on a world competition basis.

Regarding future plans, greater emphasis is being placed on field testing and initial pilot-plant operations on the more promising processes. However, research and development does not always encompass radical breakthroughs, especially where reduction of cost is the objective. The cost of converting saline water is expected to be reduced steadily through the research and pilot-plant work, thereby serving new industrial needs, and before too long, some municipal needs.

It is necessary to continue basic and exploratory research on processes as yet undeveloped. The rate of future progress must remain in-

definite, since in any research activity it is not possible to assure the attainment of a desired result at the end of a specified time.

The Department's plans for accelerating the program at this time include four steps:

1. Continue the work in basic and exploratory research.
2. Put more processes under initial pilot-plant testing.
3. Expand and continue the pilot testing of some of the processes that are already in or through their initial pilot testing.
4. Have available suitable test facilities at the sea.

Acceleration of the program is dependent upon an adequate technical and administrative staff to handle the work.

In that regard, the three technical staff members who will present discussions of processes are Mr. J. J. Strobel, chemical engineer, Dr. W. S. Gillam, physical chemist, and Mr. Allen Cywin, mechanical engineer. With me also is Mr. Ernest Sieveka, chemical engineer, and, located in North Carolina in charge of the pilot-plant work, is Mr. Edgar Cadwallader, chemical engineer.

These five men comprise my entire technical staff. I would like to say, Mr. Chairman, that the large amount of work carried out by the Office of the Saline Water, as reflected by the annual report before you, is due in a large measure to the efforts of this small but very capable group of engineers and scientists, as well as to their hard-working clerical assistants.

I feel fortunate indeed in having men of their technical capabilities at the rates we are able to pay in the Government.

And, finally, Mr. Chairman, as I mentioned earlier, this field may become highly competitive. I feel certain that greatly improved conversion processes will be developed through the saline water conversion program, both under its own research and development work and by its stimulation of private effort.

It is to be expected, therefore, that those improvements will render obsolete some present-day commercially available processes. However, creation of obsolescence is inherent in any research work designed for the overall public benefit.

Furthermore, if conversion processes are developed at prices broadly attractive to the consumer, there should be greatly increased manufacturing business in this field. Therefore, I hope that this committee will bear in mind, during these hearings of the next few days, that among manufacturers who are producing conversion equipment today, and even among others who are desirous of developing commercially profitable patents and processes, there may be a few who feel sincerely that they will be adversely affected as a result of this program.

Thank you.

Mr. JONES. Mr. Knox?

Mr. KNOX. Go right ahead, Mr. Chairman.

Mr. JONES. Mr. Jenkins, you in the first paragraph of your statement identified the program as "Federal aid under this very small Government program," and so forth. In the last paragraph on the first page you refer to "the research on processes under the Federal-aid program."

Now, do you think that this is a Federal-aid program? Or a Federal program—period?

Mr. JENKINS. I have viewed the contract research work in the light of Federal aid in the broad sense.

Mr. JONES. Well, I understand that, but you do not sense that this is a legislative effort to get somebody else to do the thinking and you would help them if they would think to do the work, do you? That is what Federal-aid programs mean to me—that somebody else is doing it and we will help you if you do it. The initiative has got to be on the other end.

Now, are we in the Department of Interior, in the Office of Saline Water, thinking up these ideas? Or are we waiting for somebody to come along with them, with ideas to put to work?

Mr. JENKINS. Mr. Chairman, the method by which we have operated under the law that was enacted in 1952 was to encourage private research and development work and to supplement that private research——

Mr. JONES. Well——

Mr. JENKINS. With a small amount of Federal money.

Mr. JONES. I am not talking about that now, Mr. Jenkins, because the outline of how you would go about achieving the objectives set out—either by contract or by use of cooperative agreements between the States, private industry, or any organization dedicated to the same proposition—is sensed under this legislation. But there is nothing in the act or in the amendment that describes it as a Federal-aid program.

It is a Federal responsibility. And it seems to me if we think of it as a Federal-aid program, then we vacate the Federal responsibility and await the pleasure of some industry or some State or some university to get excited about a certain inquiry on eliminating salt from water.

Mr. JENKINS. I think that my only response to that can be that in the beginning of the program this method of operating was laid out and described to every committee before whom we met almost—the Appropriation Committees and others—and they all seemed to feel that this was the proper way to proceed. We have never had this question raised by one of the legislative or appropriation committees before.

Mr. JONES. Well, I am not finding any fault with the way that you proceed. I am finding fault, if I understand your use, with this program being a Federal-aid program. Because nowhere in the act does it say or give any indication that this is a Federal aid program but, instead, it puts it that this is going to be a task of the Federal Government.

One of the reasons why, is its defense significance. Another is the great need throughout the Nation for the changing of saline water to water of quality for agricultural, industrial and municipal usage.

Mr. AANDAHL. May I offer a statement, Mr. Chairman?

Mr. JONES. Yes, sir, Mr. Secretary.

Mr. AANDAHL. I think that probably Mr. Jenkins has used the expression "Federal aid" somewhat differently than the meaning that Members of Congress generally have with respect to what we commonly think of as the Federal-aid programs. I think he has used the expression here to distinguish——

Mr. JONES. Do you, Mr. Jenkins, accept the Secretary's explanation of what you mean?

Mr. AANDAHL. Let me complete it, please—to distinguish between a program that is conducted by a Federal laboratory with all federally

employed scientists and technicians doing the work, as contrasted to a program in which we contract and offer grants to research institutes and to universities to go ahead with specific work that we in the Office of Saline Water have decided should be promoted.

Mr. JONES. Yes, sir. Well, I understand that, Mr. Secretary.

Mr. JENKINS. May I respond further?

Mr. JONES. Yes.

Mr. JENKINS. The act in section 2 does authorize the Secretary to carry out research and development work but specifies how he shall do that.

Mr. JONES. Yes, sir; I understand.

Mr. JENKINS. By means of research grants and contracts.

Mr. JONES. Yes, sir.

Mr. JENKINS. And then in 1955 a portion of the funds were specifically indicated for work in Federal laboratories and still leaving a portion definitely for research grants and contracts.

Mr. JONES. I am not finding any fault with that or how you have carried it out. The point that is disturbing about it is where these ideas are going to be born. Where is the sperm?

Now, it seems like these ideas should originate in a great number of cases with your people, and then you go out and seek somebody, some university or some private concern, to take on the task of developing and seeing just what you described with this professor up at the University of New York.

Well, I hope that that is not the meaning of this program in the sense that it is something like Damocles' sword—to be suspended in midair waiting till somebody walks under it before you pull the string.

Mr. JENKINS. No, sir; definitely it is not. In the beginning of the program, when we distributed this outline of processes to many people, it was felt at that time that this was a way to bring in the thinking, the technical thinking, of literally dozens of people whom we could not employ in our office.

Certainly within the Office of Saline Water, even with the staff that we have, there have been a number of new ideas that have been proposed. Four or five of our better ideas have been proposed and incorporated into some of the work that was underway, or new work initiated.

And with any increase in staff we would have that much more opportunity to give scientific thought.

Mr. JONES. Well, I am relieved to know that that is your thinking on the proposition that I have raised.

Yes, Mr. Knox?

Mr. KNOX. Mr. Chairman, I think the act is very specific. It was set up for a specific purpose, and that was to develop a medium in which we could convert sea water into usable water for domestic purposes.

However, I do note in paragraph (e) of section 2 that it specifically states:

> To cooperate with any other Federal, State, or municipal department, agency, or instrumentality and with any private person, firm, educational institution, or other organization in effectuating the purpose of this Act.

So I would suppose that under that paragraph, if some State should start on a program, that it was the intent of Congress that the Federal Government should step in and assist in every way possible in order to help them develop their particular program that they set up in the respective State; is that true?

Mr. Aandahl. Yes; that would be correct. That is, we should coordinate our efforts and, insofar as it is advisable, make them joint ventures.

Mr. KNOX. Well, of course, I do not like to see the Department take the view that it is a Federal-aid program either, but I do not think that that has been the determining factor as far as the Department is concerned. I think you possibly have taken the initiative, but because of the fact that Congress wrote into the act that you were to cooperate with other Federal, State, or municipal agencies there would be some justification possibly for giving of the funds or supplementing their funds with Federal funds in order to effectuate the program which was initiated possibly, we will say, by a State or some municipality.

Mr. AANDAHL. I think that we should distinguish quite sharply this from the use of Federal aid in our highway program and our aid to education program.

Mr. KNOX. Yes; I would hope you would.

Mr. AANDAHL. Where the responsibilities are primarily State responsibilities and there is Federal aid to those programs.

Mr. KNOX. That is correct.

Mr. AANDAHL. Now, in this case we give some financial aid to research work which others are doing, but it is being done under the direction and overall supervision and I hope inspiration of the Office of Saline Water.

Mr. KNOX. Well, I join with the chairman's concern relative to the usage of the words "Federal aid," because I do not believe it was the intent of Congress that it was to be a Federal-aid program. And, of course, your interpretations I think have been well established in justifying what you were using the Federal funds for.

Mr. AANDAHL. Yes; I feel our thinking and our basic purpose are identical here.

Mr. KNOX. In the first paragraph of your statement, Mr. Jenkins, you start off by saying:

> Ever since the saline water conversion program was begun in 1952, we have invoked precautions and safeguards.

Would you care to inform the committee as to just what precautions and safeguards you have invoked in the program?

Mr. JENKINS. Yes, sir. I had reference there principally to the methods of examining the research and development work that is to be undertaken. This is a very small program. There have been literally hundreds of applications, if they may be called that, proposals of different kinds, and ideas, submitted to the Department. Some have been accompanied by very insistent requests for favorable consideration.

Now, I have recognized that this would be the case in the beginning because of a backlog that we had of some of these ideas, a few of which were scientifically sound—not many.

Therefore, we established in the beginning a system patterned considerably after that of the National Science Foundation for evaluating these applications. We receive the applications, screen them in our own small staff. If they are technically feasible in any way at all, they are then sent to a number of outside consultants, consulting engineers and consulting engineering firms, scientists, each one of which is a specialist in his field. And the number of that group and their capabilities far exceed, of course, what we could employ in our office. And, thereby, we draw upon that very capable group of about 60 all together.

These applications or requests for assistance or for work on a new process are examined very carefully and critically by a selected panel in that group. That again follows the National Science Foundation pattern.

Mr. KNOX. May I at that point raise a question relative to private industry or private capital that has entered into the program and requested assistance from the Interior Department in the development of their particular project? Would you care to comment on how many and as to what the results have been from the applications where the Interior Department has joined with the industry in the development of the program?

Mr. JENKINS. I would say, Congressman Knox, that the results in general have been very good—probably for one reason. When private industry is interested, it usually is interested in something that has reached the hardware stage or is heading into the pilot-plant stage. Few industrial organizations come to us for basic research assistance.

In most cases, they themselves have screened these ideas rather well. And it has been our experience that industry just does not have the scientific manpower to spare on a development unless it is pretty good.

Mr. KNOX. At that point, then, may I request that you inform the committee as to what assistance has been given by your Department, whether it has been through the dollar sign or through the loaning of scientists and engineers in the field?

Mr. JENKINS. Quite a bit of this work has been actually on a cooperative basis. We have entered into contracts where the work is specified in the contract—as to what shall be done. The Office of Saline Water of the Department finances this work. But in a number of cases the industrial institution has contributed also, has contributed directly.

Mr. Cywin will discuss some of the contributions made in one of our pilot-plant activities in North Carolina. Those have been quite major contributions. Ionics, Inc., whom we worked with a great deal, I expect expended more money than the Government did in its development. I am sure of that.

Mr. KNOX. In other words, you are informing the committee that there has been a fine cooperative program in the form of technical work by industry along with the Department in the attempt to solve these problems that are confronting the Nation today as far as the conversion is concerned?

Mr. JENKINS. Yes, sir. Their cooperation has been excellent.

Mr. KNOX. Fine.

Mr. JONES. Anything further, Mr. Knox?

Mr. KNOX. I do not believe I have at the moment, Mr. Chairman.

Mr. JONES. Mr. Jenkins, on page 6 of your statement, item 4, you say:

**Have available suitable test facilities at the sea.**

Do you mean those areas near the seashore?

Mr. JENKINS. Yes, sir. A laboratory or a test facility is needed where we have a continuous supply of fresh, undiluted sea water.

Mr. JONES. I see.

Mr. JENKINS. There are a number of laboratories of the Department of Interior, inland. One in Denver and some others. None is at the seashore, unfortunately. We have borrowed the facilities of the International Nickel Co. at Harbor Island, N. C. They are most cooperative.

We feel that some more reliable or permanent test facility at the sea is necessary. That might be through obtaining one that would be owned and operated by the Government or one that would be perhaps operated by a university or research institution.

However, in this case, I would eliminate private industry from operating such a test facility. We, in fact, had offers to use test facilities of one private industry that is engaged in manufacturing conversion equipment. That is considerably unlike using the facility of the International Nickel Co. which has no process itself. I would not believe that such testing, by any interested industrial organization, of Government developments, would be desirable.

Mr. JONES. Mr. Indritz?

Mr. INDRITZ. Before I ask you any questions, Mr. Jenkins, I wonder, Mr. Secretary, if I may ask one more question of you?

Mr. AANDAHL. Yes.

Mr. INDRITZ. In response to the chairman's letter to Secretary Seaton inviting him to appear before this subcommittee also, Secretary Seaton in a letter dated April 11, 1958, which we received 2 or 3 days ago indicated that the Department is having a review made of the saline water program and that he expects to have the review completed very shortly.

I understand that the same statement was also made to the House Appropriations Committee on January 13 of this year.[4]

What is the status of that review, and when might it be ready?

Mr. AANDAHL. I do not know when the Secretary may have anything further to offer. I know that he and his staff are reviewing most of the programs in the Department of Interior constantly, and he has given a great deal of attention to the saline water program. But I do not have any specific information as to just how soon he may have something to issue.

Mr. INDRITZ. May we have a copy of that review when it is completed?

Mr. AANDAHL. I am sure the Secretary will be glad to give you any information that he completes.

Mr. JONES. Mr. Secretary, will you supply us with that review, or do you think that it would be best for the committee to request that information?

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[4] P. 3, hearings before subcommittee of Committee on Appropriations, House of Representatives, 85th Cong., 2d sess., on Department of the Interior and related agencies appropriations for 1959 fiscal year.

Mr. AANDAHL. I think it would be just as well that you make a specific request to the Office of the Secretary.

Mr. JONES. Well, then, we will make that request.

Mr. KNOX. Mr. Secretary, I should like to inquire relative to your testimony in which I believe you testified that the present staff that was now engaged in the saline water program was adequate to carry on. Is that correct?

Mr. AANDAHL. Well, I indicated that the staff would need to be increased with any expansion of the program. And if we get the supplemental appropriation that we are in the process of requesting for 1959, I am sure that will enlarge the program to the point where we will need additional staff people.

Mr. KNOX. In other words, if the program is accelerated, then, of course, there is only one way to accomplish it and that is to have additional staff in order to reach your objective?

Mr. AANDAHL. That is correct. The staff that we have now is tremendously busy. I do not know of any office in the Department of Interior where the staff is more constantly busy than they are in the Office of Saline Water. They are a very, very hard-working group. And I know if we have an expanded program we must expand that setup.

Mr. KNOX. Well, my reason for asking for information on it was that Mr. Jenkins had stated in his fourth recommendation that acceleration of the program is dependent upon adequate technical and administrative staff to handle the work, which was somewhat indicative that possibly he did not have sufficient staff if the program was going to be accelerated. I did not want to have conflicting testimony, and I thought we should clear it up.

Mr. AANDAHL. That is entirely correct.

Mr. KNOX. Your statement when you were testifying is in conformity with what Mr. Jenkins has said?

Mr. AANDAHL. That is correct.

Mr. KNOX. That is all I have, Mr. Chairman.

Mr. JONES. Well, Mr. Secretary, I have the letter of April 11 from the Secretary in which he stated that the report which Mr. Indritz has inquired about is being prepared, and he says, more specifically:

> Steps have been taken to assure that the review will be completed and submitted to me at an early date.

Then in the Senate Appropriations Subcommittee hearing, on March 26, 1958, on the Interior Department and Related Agencies Appropriations for 1959, at page 74, in a question propounded by Senator Hayden, the Senator requests a copy of the report. He says:

> Is it completed?

The Secretary answered:

> Yes, I think so. * * * That report will be compiled and will be available shortly if you would like to have it sent to the committee.

So, therefore, I presume that a copy of it will become available shortly, and we will request the Secretary to accommodate us by sending a copy of that report.

Mr. AANDAHL. Yes. Again I must say——

Mr. JONES. I understand.

Mr. AANDAHL. I am not informed as to the time it will be ready. But when such a report is ready, it will be available to your committee just as well as to the Appropriations Committee.

(On written request of the subcommittee chairman, the Department of the Interior furnished the following information:)

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
*Washington, D. C., May 19, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*Committee on Government Operations,*
*House of Representatives, Washington, D. C.*

DEAR MR. JONES: With reference to your letter of April 21, 1958, concerning the review of the saline-water program, receipt of which was acknowleged on April 29, 1958, I am pleased to advise that the review suggests the following summary:

The meeting on March 25, 1958, with the group of eminent representatives of scientific, educational, and industrial organizations who provide consultation and advice to the Secretary on this activity was an important step in reviewing the saline-water conversion program. The following recommendations came from that group:

1. Program should be accelerated through stepped-up appropriations making full use of the existing authorization.
2. Existing authorization should be spent for research and initial pilot-plant development.
3. Large pilot plants should come from addtiional authorization and earmarked appropriations which are recommended.
4. The duration of the saline-water program should be extended beyond the existing authorization.
5. We should foster foreign contacts and have at least one research project outside the United States which would serve to encourage others.
6. We should encourage cooperating in a foreign demonstration plant in exchange for technological information to the Office of Saline Water, regardless of what Government agency would be involved.
7. Availability of a seaside test facility would be extremely desirable.
8. Basic and exploratory research must be continued.
9. There is an urgency in California which requires definitive conclusions within 6 to 8 years relative to the California water plan.
10. An increased effort should be made to inform the public of the program, progress, and responsibilities.
11. Office of Saline Water should be commended for the excellent progress to date with the limited funds available.

Recommendation No. 1 has been approved, and the request for a supplemental appropriation of $530,000 to implement it is now being processed. It will be our purpose to follow this pattern during the remaining years of the authorized program.

Recommendations 2, 5, and 8 are basic under present authorization and will be guiding principles in the use of appropriations under recommendation 1.

Recommendations 3 and 4 require legislation, and our request for it will depend somewhat on results of present work and will not be ready until a subsequent Congress except for such reports as we make on bills now pending.

Recommendations 6, 7, 9, and 10 can be fitted administratively as experience and appropriations justify and permit.

Since its inception in 1952, the program and the work in saline-water conversion have been constantly expanding to be progressively fully responsive to the authorizations made by Congress. The growing requirements for water and the urgency for means of converting saline and brackish water in some areas fully justifies what has been done. The progress and preliminary results of the work associated with the expanding need prompt continuing acceleration. Gradual building up of the program gives maximum efficiency to the work and greater accomplishments from the money spent.

The work to be undertaken within the coming year is as follows: Continue and complete the field testing of the Hickman rotary still and make engineering studies of larger units; prepare engineering designs of the W. L. Badger long tube vertical distillation pilot plant having a capacity of approximately 1 million gallons per day; construction and operation of a number of pilot model solar stills at a seaside location to reduce material costs and improve production; evaluation of existing electrodialysis (brackish water) systems and engineering designs of larger, lower cost, practical units; development of a medium-size pilot osmionic equipment and a small osmionic unit; construction and operation of small pilot plants for the freeze-evaporation and the solvent-extraction processes; expanded exploration and initial design of combination multiple-purpose plants utilizing nuclear energy with saline-water conversion and, possibly, including production of byproducts; and increased emphasis on exploratory and basic research and stimulation of original scientific study for the purpose of developing wholly new approaches. There is an urgent need to have Government experimental facilities at a seaside site where prototype process equipment and small pilot plants can be emplaced and operated under field conditions with essential minimum laboratory shop and research facilities, together with some increase in highly specialized scientific personnel in accord with the progressively expanding research and pilot-plant activity.

Sincerely yours,

D. OTIS BEASLEY,
*Administrative Assistant, Secretary of the Interior.*

Mr. JONES. Yes.

Mr. Indritz?

Mr. INDRITZ. Thank you, Mr. Secretary.

Mr. Jenkins, on page 5 of your statement you said, and I quote:

Of greatest importance, perhaps, is the fact that the calculations—

that is, of the standard cost procedure—

include all real costs of conversion.

Now, we have examined copies of the standardized cost procedure, and there seem to be a number of costs which are not included. For example, there is no provision for the cost of water or for the cost of storage of raw water or for disposal of waste, including concentrated brines. The fuel costs seem to be low in comparison to present-day fuel costs. I wonder if you would comment on those omissions?

Mr. JENKINS. Yes. My statement was intended to refer to the costs of conversion alone, without storage. The matter of storage, of course, could be very expensive. We all know that. Now, there is included a small amount for storage as one of the initial plant costs of storage for 10 days. This is not storage for a year or two, as we speak of reservoirs, however.

Mr. INDRITZ. But isn't that only the product water, the pure water after it comes out of the plant?

Mr. JENKINS. Yes. This would be to accommodate shutdowns and——

Mr. INDRITZ. But have you any costs allocated for storage of the raw water?

Mr. JENKINS. Yes; there is a small amount of storage for raw water. Page 3.

Mr. INDRITZ. What about costs for disposal of concentrated brines? That may be a very substantial cost, may it not?

Mr. JENKINS. Yes. At the seashore this is not a very great problem.

Mr. INDRITZ. But the cost of disposing of saline water was, perhaps, the motivating reason for the electrodialysis project undertaken by the Union of South Africa? Is that not so?

Mr. JENKINS. I believe that they had a disposal problem. They were not permitted to place mine waters in the streams. We have reports from them, but, as to their handling of the concentrated brine stream, I am not familiar with what they are doing. Perhaps Dr. Gillam is. But I do not believe that they have grappled with this problem of the storage or disposal of the concentrated brine. If they have, Dr. Gillam knows about it.

Dr. GILLAM. Well, Mr. Jenkins, they are ponding this brine——

Mr. JONES. Let me make this suggestion. Suppose we try to get along. Now, I am sure that that problem was a difficult problem in South Africa, but let's relate it to the cost. It has nothing to do with the estimates of cost of research and development that you have figured in your projects, has it? The South African project?

Mr. JENKINS. Not the South African project as such.

Mr. JONES. All right.

Mr. INDRITZ. But certainly in connection with desalinization inland, areas.

Mr. JONES. Yes, sir. All right. Now, let's stay with that, and we will not have to ask everybody around the table and we will have some order to the procedure I think. Not that we do not want to hear from your good doctor; we are going to before this hearing is over.

Mr. INDRITZ. But certainly in connection with desalinization inland, in inland areas, you may find a very substantial problem—that disposal will substantially increase the costs. Have you conducted any research on that?

Mr. JENKINS. Yes, we have. We have recognized that problem, and we let a very small consulting undertaking to some people in Texas to examine this very problem and to see if they could recommend the best means of disposing of the brine.

Mr. INDRITZ. But those costs are not reflected in your standardized cost estimate?

Mr. JENKINS. This is cost estimating of conversion, for comparison of one conversion process with another.

Mr. STROBEL. I think there is an explanation, Mr. Jenkins, here right in the cost estimating procedure on page 8, the paragraph at the bottom of page 8.

Mr. JENKINS. This has been considered, but we have not solved the problem.

Mr. INDRITZ. Do the fuel costs utilized in the cost estimating procedure reflect current costs of fuel?

Mr. JENKINS. The entire procedure as set forth in the first preamble—and as I stated in my testimony—is and must be considered flexible. And that means to accommodate local conditions.

It is recommended here that cost estimates given in this procedure be used only when the actual costs are not known.

Now, we have used certain fuel cost recommendations here. This was developed in 1956, as I said, and we are bringing it up to date as we go along.

But the person who uses it is instructed to adopt whatever costs, whether it is fuel or labor, power, or whatever it may be, in accordance with his local conditions.

Mr. INDRITZ. For example, fuel is indicated as 25 cents per million B. t. u.'s. That would, as I understand it, make it a dollar and a quarter per barrel of bunker C fuel oil. I understand that the price for that oil is considerably higher than that. Therefore, are you saying that the item for fuel would have to be, not 25 cents, but much larger, perhaps 50 cents?

Mr. JENKINS. It might be larger, Mr. Indritz, or it might be smaller, depending upon the local condition. There are some areas in Texas, I believe, where we still have considerable natural gas which costs less per million B. t. u.'s than this amount. And certainly in some areas there would be higher costs.

Mr. INDRITZ. So that in terms of making comparisons between different processes, you would have to take into account the different regional costs, geographical differences of labor costs, labor efficiency, cost of fuel, and other special costs?

Mr. JENKINS. Exactly. And that is stated in the foreword to the procedure.

Mr. INDRITZ. How much do you think that water users can afford to pay for water?

Mr. JENKINS. This is a subject which I would prefer to discuss after Dr. Leopold has given his testimony. He goes into this subject at some length. And then we have made some estimates also.

Mr. INDRITZ. There has been a recent construction of a very large plant at Kuwait by Westinghouse, and some of the estimates that have been made as to the costs are below a dollar per thousand gallons. Have these estimates been calculated on the basis of the standardized cost procedure?

Mr. JENKINS. Yes, on the basis of the standardized cost procedure—this is Westinghouse—total water cost comes out $1.13 a thousand gallons.

Mr. INDRITZ. Not including byproduct power?

Mr. JENKINS. Yes, not including sale of byproduct power.

Now, I should make this clear: That in that particular instance the cost of the fuel, gas, is zero. The plant was designed around this fact. They have only a four-stage plant, which was designed to make maximum use of investment cost and without regard to fuel cost.

Where there would be a different type of fuel, if there were to be cost for the fuel, there would be a different type of plant built.

Mr. INDRITZ. Thank you.

Now, you have sent us copies of some of the contracts that you have with some of the contractors under the Office of Saline Water program. And we have noticed that some of them have a provision that—

**The contractor agrees not to publish or make available for publication, or make available to others except representatives of the Contracting Officer, the results of or any information concerning said research investigations without approval in writing from the Contracting Officer.**

Mr. JENKINS. Yes, sir.

Mr. INDRITZ. Could you tell us the purpose of that clause?

Mr. JENKINS. Yes, sir. We have felt that partial results, unproven, interim results, that come along month by month, if released to the general public, would only be misleading. And we have, therefore, included in all contracts that the release of information should not be made by the contractor.

A second reason is that I have felt that that is a responsibility of the Government office itself to make such releases, when they are of a nature that the information can be released, in order that all people receive the information and that we run no chance of having 1 or 2 people receive it preferentially.

Mr. JONES. In other words, you are not trying to withhold information but to determine the reliability of the information before it is disclosed?

Mr. JENKINS. Yes, Mr. Chairman, and then to be sure it is disclosed to everyone.

Mr. INDRITZ. Now, how soon after a final report is made available by the contractor is the report released?

Mr. JENKINS. As soon as it is reviewed and evaluated by our consultants, if that is necessary, or by our staff of our office, in order that errors or inadvertent misstatements are not released to the public. And the Government assumes that responsibility, you see.

Mr. INDRITZ. How long a time lag is that?

Mr. JENKINS. It varies from 1 to 3 months I would say. And it depends. There are some results which can be placed in open file. We do that sometimes when publication does not seem justified. And some of them can be released rather quickly. It depends on the extent of the review needed.

Mr. INDRITZ. Has there been any final report presented by a contractor more than 3 months ago which has not yet been released?

Mr. JENKINS. I would have to check that and see. I do not think there have been, although there were some negative reports, and perhaps 1 or 2 affirmative reports that may be 3 months old by now.

Mr. INDRITZ. Could you check, and if you find any report older than 3 months which has not yet been released, advise the subcommittee of the name of the contractor and identify the report and the date it was submitted?

Mr. JENKINS. Yes.

(The information requested is as follows:)

*Saline water conversion research and development reports more than 3 months old which had not been placed in open file on Apr. 16, 1958*

| Contractor | Title of contract | Date report submitted by contractor to OSW | Date report made available for public inspection | Time interval between submission and public release of report |
|---|---|---|---|---|
| | | | | *Months* |
| University of California, Los Angeles, Calif. | Research and development of molecular oil films for use in the large-scale low-cost demineralization of saline waters by a pressure method. | Oct. 18, 1956 | Apr. 23, 1958 | 18¼ |
| Allied Industries, San Diego, Calif. | Experiments to determine whether saline water can be demineralized by application of an ultra-high electrical field. | July 15, 1955 | ....do.... | 33 |
| University of Iowa, Iowa City, Iowa. | Research on demineralization of saline waters by pressure permeation through microporous membranes. | Nov. 15, 1957 | ....do.... | 5¼ |
| Applied Science Laboratories, State College, Pa. | Exploratory research on salting out natural salts from sea water. | Oct. 7, 1957 | ....do.... | 6½ |
| Louis Koenig Research, San Antonio, Tex. | An orientation study on disposal of saline water conversion brines. | May 3, 1957 | ....do.... | 11¾ |
| Applied Science Laboratories, State College, Pa. | Research on increase in saline ice crystal dimensions and on flotation methods for separating entrained salt from saline ice. | Mar. 4, 1957 | ....do.... | 13¾ |
| Resources Research, Washington, D. C. | Survey of physiological mechanisms of sodium and chloride ion transport and design of experiment for application to demineralizing saline waters. | Oct. 15, 1957 | ....do.... | 6¼ |
| University of Minnesota. | Development of a comprehensive working procedure for making a survey of waste heat potentially applicable to large-scale low-cost demineralization of saline water. | Nov. 1, 1954 | May 9, 1958 | 42½ |
| University of Florida.. | Investigation of possible use of ultrasonics in the demineralization of saline waters. | June 7, 1955 | ....do.... | 35 |
| W. L. Badger..... | Plans, specifications, and test procedures for investigating sea water scale prevention in long tube vertical evaporators. | Oct. 11, 1956 | ....do.... | 19 |

Mr. INDRITZ. How do you disseminate information about your program?

Mr. JENKINS. First through the annual reports, which have a very broad coverage now. I expect we distribute two or three thousand of those annual reports. Through press releases concerning important new contracts that are let and important final results that are obtained. Also other press releases concerning the availability of reports in open file.

Then the technical press has assisted us very much in reporting on the work of the Office. The lay press has been of very great assistance, too. They have come to us and obtained information from time to time.

As you know, it is a fascinating subject. Many people wish to write about it. We give them all the help we possibly can.

In addition, we have engaged in a very small amount of technical writing ourselves and presentation of technical papers at technical meetings. I say a very small amount because we just do not have the staff to conduct much of that work.

I should say that Dr. Gillam and Mr. Strobel have prepared a technical paper covering the entire subject for presentation today in San Francisco at the American Chemical Association, and Mr. Cadwallader is out there presenting it for them.

Mr. INDRITZ. Is your staff available to newspapermen and journalists and others seeking information?

Mr. JENKINS. Yes, indeed.

Mr. INDRITZ. We notice that you have different types of patent clauses in your contracts. Would you indicate when you use the different types?

Mr. JENKINS. There are just two types, and either may be used.

In the one, the Government takes title to the patent, and in the other the Government receives a nonexclusive license to use the patent for governmental purposes.

These are used in different contracts, largely in accordance with the practice of the organization that we are contracting with. We have to meet their requirements, too. And that is why two provisions were adopted rather than just one.

With universities, research institutions, which are usually not interested in retaining the title to a patent, the first one that I mentioned is used. With industrial organizations, usually the second is used.

(The patent clauses referred to are as follows:)

PATENT PROVISIONS NOW USED IN OFFICE OF SALINE WATER CONTRACTS

NO. 1. PATENT ASSIGNED TO GOVERNMENT

Contractor agrees that it will promptly disclose to the Government all discoveries and inventions made within the scope of this contract, and that it will, upon request, assign and transfer to the United States, as represented for this purpose by the Secretary of the Interior, full and entire right, title, and interest in and to such discoveries or inventions. Contractor warrants that it has full authority to make such assignments by reason of existing agreements by all of its scientific personnel who will be engaged in work on the project to assign to the contractor all discoveries and inventions made within the scope of their employment.

NO. 2. LICENSE TO GOVERNMENT

It is agreed that the contractor may retain all domestic right, title, and interest in and to any invention conceived or first actually reduced to practice during and as a result of the research and development under this contract, subject to a royalty-free, nonexclusive license to the Government to use and practice such invention for governmental purposes, in consideration for which the contractor agrees that it will issue nonexclusive licenses at reasonable royalties to all qualified applicants. Disposition of foreign patent rights to any such invention shall be determined by the United States. The contractor shall report promptly to the contracting officer each application for patent or any invention under which the Government is entitled to a license hereunder, and of any foreign application to which it may retain rights by reason of the Government's determination. Prior to completion or final settlement of this contract, the contractor shall disclose to the contracting officer each invention under which the Government is entitled to a license hereunder, either by giving the patent number or a copy of the patent application, and shall also deliver to the same duly executed instruments confirmatory of such license rights. If to the best of the contractor's knowledge and belief no inventions have been conceived or actually reduced to practice during and as a result of the research and development under this contract, the contractor shall so certify to the contracting officer.

NO. 2A. WITH CONTRACTOR HAVING FOREIGN PATENT RIGHTS

It is agreed that the contractor may retain the entire right, title, and interest in and to any invention conceived or first actually reduced to practice during and as a result of the research and development under this contract; *provided, however,* That with respect to patent rights in the United States, the contractor agrees to grant to the Government an irrevocable, royalty-free, nonexclusive license to use and practice such invention for governmental purposes, and further agrees that he will grant nonexclusive licenses at reasonable royalties to all qualified applicants.

The contractor further agrees to grant to the Government an irrevocable, royalty-free, nonexclusive license to use and practice such invention in foreign countries for governmental purposes. The contractor will grant such foreign licenses to the extent that the contractor has the right a grant the same without incurring any obligation to pay royalties or other compensation to others solely on account of said grant.

The contractor shall report promptly to the contracting officer each application for patent on any invention under which the Government is entitled to a license hereunder. Prior to completion or final settlement of this contract, the contractor shall disclose to the contracting officer each invention under which the Government is entitled to a license hereunder, either by giving the patent number or a copy of the patent application, and shall also deliver to the same duly executed instruments confirmatory of such license rights. If to the best of the contractor's knowledge and belief no inventions have been conceived or actually reduced to practice during and as a result of the research and development under this contract, the contractor shall so certify to the contracting officer.

EXAMPLE OF COVERAGE OF BACKGROUND PATENTS (NOT A STANDARD PROVISION)

It is recognized that the apparatus to be tested under this contract involves United States patent application, Serial No. ------ (or Patent No. ------), and that the Government has no proprietary interest in such patent applications. However, in view of the Government's proposed assistance in developing and testing the apparatus, the contractor hereby grants to the Government an irrevocable, nonexclusive and nontransferable license to make, have made and use for governmental purposes, and to dispose of, according to law, any embodiment of the invention incorporated in said patent application. The Government agrees to pay and the contractor agrees to accept as a reasonable royalty with respect to any such patented invention, sums not exceeding the percentage of the cost to the Government of the apparatus to be made by or for the Government under such license as follows:

| | | | |
|---|---|---|---|
| First---------- | $------ | of cost to the Government | ------ percent. |
| Next---------- | ------ | of cost to the Government | ------ percent. |
| Next---------- | ------ | of cost to the Government | ------ percent. |
| All over---------- | ------ | of cost to the government | ------ percent. |

The cost to the Government of any parts manufactured pursuant to the Government royalty-free license under the first two paragraphs of this article, which are readily separable both physically and from the standpoint of standard applicable accounting practices shall be deducted from the cost to the Government of the entire related machine for the purposes of the above computation.

Mr. INDRITZ. Now, in addition to obtaining a royalty-free, nonexclusive license to the Government, some of the clauses that we have seen in your contracts also provide that the contractor is to grant a nonexclusive license at reasonable royalties to all qualified applicants. That provision apparently is to assure that knowledge will not be withheld or monopolized and that the license would be available to all people. Do you insist on the inclusion of that clause in every contract?

Mr. JENKINS. We do at the present time. In the beginning, it took a little time to work out our patent policies, and some of our earlier contracts reflect this development of a patent policy. The Department of Defense and others I believe do not have that last clause.

Mr. INDRITZ. But you regard this as an improvement, do you not?

Mr. JENKINS. I do.

Mr. INDRITZ. And at the present time you do have that clause for license to all applicants at reasonable royalties in all contracts which provide for simply a license to the Government rather than an assignment of the patent to the Government. Is that correct?

Mr. JENKINS. Yes.

Mr. INDRITZ. Has there been any thought given to including in the patent clause a provision for determining what is a reasonable royalty and who is to determine the reasonable amount of the royalty when an applicant applies for a license?

Mr. JENKINS. That has been discussed at some length, and our people in charge of the patent work in the Department have not viewed this as an unsurmountable problem. The determination of what amounts to a reasonable royalty is made fairly well, fairly easily, at the time that something has been developed.

Now, in a few cases, Mr. Indritz—one case, I should say, only one—we have written into the contract a stipulated set of royalties that would be paid by the Government for background patents that were developed earlier. We have tried without success to do this in some other cases.

Mr. JONES. Well, Mr. Indritz, we will recess until 2 o'clock.

We will stand in recess until 2 o'clock.

(Whereupon at 12:48 p. m., the subcommittee recessed, to reconvene at 2 p. m., this date.)

AFTERNOON SESSION

Mr. JONES. The meeting will come to order.

Mr. Fascell, this morning we heard from the Assistant Secretary of the Interior, Mr. Aandahl. We have this afternoon, Mr. David S. Jenkins, Director of the Office of Saline Water, Department of the Interior, who, just before we recessed for lunch, had concluded his general statement and is now being examined by the staff, which has been partly completed but there are some questions still remaining to be asked.

Mr. FASCELL. Thank you, Mr. Chairman.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. Mr. Jenkins, are all your contracts negotiated contracts or are they advertised contracts?

Mr. JENKINS. Mr. Indritz, all our contracts so far have been negotiated.

Mr. INDRITZ. Do you have provision in the contracts to insure that the records of the contractor shall be available to Government representatives?

Mr. JENKINS. Yes, sir. This is contained in every contract, that the record shall be available for inspection at any time.

Mr. INDRITZ. Including the customary provision that it be available, for a period of 3 years after the final payment, to representatives of the Comptroller General?

Mr. JENKINS. This is not specifically included in the contract. I would like to ask our attorney, Mr. Gantt, who handles the contracts, to respond to that if I may.

Mr. INDRITZ. Certainly.

Mr. GANTT. No, we don't include—let us say that is a requirement that only applies to contracts pursuant to the Federal Property and Administrative Services Act of 1949 and the Armed Services Procurement Act of 1948. We don't have such a requirement in the Saline Water Act.

Mr. INDRITZ. That is a requirement not only under those two statutes, but under some others, such as the First War Powers Act—and in fact in most of your contracts you do have, I believe, such provision. I have, however, observed that it is missing in some contracts. You put it in some, why not in others?

Mr. GANTT. Well, we would put it only in those contracts which are negotiated under delegation from the General Services Administration, or those which are entered into under the First War Powers Act.

Now, in the saline water business, you don't have to resort to that authority because the act itself is broad enough to be the negotiating authority. But the answer is, as part of my legal function, I determine it is not necessary to include——

Mr. INDRITZ. As a matter of law?

Mr. GANTT. As a matter of law. And if a lawyer can venture, as a matter of policy.

Mr. INDRITZ. Would it not be more protection to the Government to have available in negotiated contracts under the Saline Water Act, just as under the Federal Property and Administrative Services Act, the Armed Services Procurement Act and the First War Powers Act, a provision authorizing the representatives of the Comptroller General to have access to the records, until 3 years after final payment?

Mr. GANTT. I do not think it is objectionable, but I do not feel any need for it personally; because a contractor today, even without specific statutory authority, would have to retain or maintain these contracts at least 6 or 7 years, until the statute of limitation expires, in which you can go into the Court of Claims. And then under our income-tax laws, he probably would be wise to retain for a longer time.

Then if he has to retain them, the Comptroller General may in certain circumstances have difficulties in looking into the contracts, but by such investigating committees as yours, the contracts could be examined.

But let me say this, we had in saline—to my knowledge we never had any litigation. That shows that there was no specific need for such a provision; because only if you feel there is a need for the requirement, then you would——

Mr. INDRITZ. Would it not be more protective to the Government's interests to afford to the Comptroller General the opportunity to audit the contracts and examine the records?

Mr. GANTT. Yes, but the Comptroller General has anyway a post-audit of contracts.

Mr. INDRITZ. But only with respect to the Government's records, not with respect to the records of the contractor——

Mr. GANTT. Correct.

Mr. INDRITZ. In the absence of such clause.

Mr. GANTT. Correct. If your question is whether we would object to having a law passed which makes the customary retention period applicable to us, the answer is "no."

Of course, you have to keep in mind, speaking of contractors, the contractors are loaded with records requirement in addition to the normal contracting requirements.

Mr. JONES. Isn't the contract so unique that you could not apply the normal methods of advertising to it?

Mr. GANTT. Well, that is correct. Now, the Interior Department, as you know, Mr. Chairman, is basically an advertising department. Basically about 90 percent of our procurement and purchase business is done by the method of advertising. Therefore, those of us who are are in this type of business would tend usually more to advertise procedures.

Now, when you come in the field of research and development, the negotiating authority is a tool which is particularly adept to working out the best pricing cost, and what not, with other benefits to the Government.

So the answer to your question, whether advertising is completely out due to the uniqueness of the situation, at the present time I would say "Yes." However, if at a later stage we should come into a pilot plant type of operation, or so, there will be certain situations where I believe the Department will want to apply the normal customary advertising procedure as a matter of policy to that type of procurement.

As a matter of law, we do not have to do it. The Saline Water Act is purely a negotiating act the way I read it.

Mr. INDRITZ. But you do agree, do you not, that to have that provision granting the Comptroller General the authority to examine the contract records, would be an additional protection to the Government?

Mr. GANTT. It can be.

Mr. JONES. You mean it would be an additional cost to the Government, too, would it not, Mr. Gantt?

Mr. GANTT. There is a cost factor.

Mr. JONES. Then you would have the possibility of examining the recipient of that contract to find out if he had overexpended by his own enthusiasm for the project more than he had intended to, and that would put further restriction on the gratuities of those people who are parties to the contract, too, would it not?

Mr. GANTT. Well, let me say this, Mr. Congressman, the proper way to control the cost is through the contract instrument. Whenever you have an authority to examine the records, customarily you do it after the fact.

However, I agree with Mr. Indritz that for the overwhelming majority of Government contracting, in the negotiating field, such an authority or requirement for the Comptroller General to be able to examine the books is necessary. In our particular operation, no necessity has arisen so far.

The only way when we want to see the contractor's records would be when we want to examine their cost for which we are going to pay.

Personally, I think procedures always can be improved. Let me say we have made a reasonable attempt to determine that the Government gets its dollar's worth for what it pays. That philosophy

is also to show that we do not view this contract business in the way of a Federal-aid concept. In fact, I have always felt we took always the procedures to assure that we get the dollar's worth, which is a little bit different philosophy than perhaps other agencies apply in research and development.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. Mr. Jenkins, in addition to the contracts that you have, have you had cooperative agreements with companies?

Mr. JENKINS. Yes, sir, a few.

I have a list of cooperative agreements here. There have been three cooperative agreements. We also have an agreement with the Bureau of Standards which actually is not a cooperative agreement.

Mr. INDRITZ. That is simply a transfer of working funds.

Mr. JENKINS. Yes, because we pay all of the costs.

Mr. INDRITZ. So that is not truly a cooperative agreement where you both cooperate on the expenditures?

Mr. JENKINS. That is right.

Mr. INDRITZ. Which are the other three?

Mr. JENKINS. One with the National Science Foundation, one with the General Electric Corp., one with Du Pont.

Mr. INDRITZ. Would it not be helpful to your program and a means of securing additional support from private companies if you had more cooperative agreements, so that you would share the costs of research in endeavors where the company as well as the Government is interested in a particular form of research?

Mr. JENKINS. Yes, Mr. Indritz, I think it would.

I think it would be very desirable to have cooperative agreements where they can be negotiated. In fact, a number of our contracts, as I mentioned this morning, are of that nature where, although it is called a contract, the contractor does supply a considerable portion of the cost of the work.

Mr. INDRITZ. For example, have you had any contract with the National Aluminate Corp.?

Mr. JENKINS. We do not have an actual contract with them.

Mr. INDRITZ. The subcommittee received a letter from that company indicating that the company is very interested in research on the question of membrane replacement, the longevity of membranes, and their quality. Would not a research project with a company of that sort, which has a particular interest in one facet of your program, be one which could be financed jointly by both your organization and such a company, and thus in effect extend the impact of your funds?

Mr. JENKINS. Yes, that could be done; in this particular case, I am not sure that we would want private funds.

Mr. INDRITZ. I simply use that as an example.

Mr. JENKINS. Yes. The research undertaking there is for testing, establishing some standard tests and then evaluating various membranes. And while we would like to add that we expect to have a cooperation by exchange of information from these organizations—see, here is one area where I feel perhaps this is almost strictly a Government function, to come up with an unbiased evaluation of various membranes.

Mr. INDRITZ. Are you familiar with the practice of the Bureau of the Mines, for example, to have cooperative agreements with many

companies that are interested in particular metallurgical or other mineral processes, and in this fashion to extend the field of knowledge, which is one of the functions of the Bureau of the Mines?

Mr. JENKINS. Yes.

Mr. INDRITZ. In connection with your research program, do you have in mind not only the very large-scale plants but also the smaller type plants which could be usable in summer cottages or in household use?

Mr. JENKINS. Very definitely, Mr. Indritz. I feel that a part of this language in the law applies to that type of conversion process. For example—well, it provides for developing means of converting water on a large-scale basis.

Now, if we had one plant that produced 100 million gallons of water, that would be a large-scale basis. But if we had a million small plants that produced 100 gallons of water each, that would be on a large-scale basis also. There would be some advantage in that we would avoid considerable distribution cost.

Mr. INDRITZ. Are there any processes now ready for such use? Specifically, are the electrodialysis unit and the Hickman still almost at the stage for such use?

Mr. JENKINS. I would say that the Ionics electrodialysis unit is ready for that use now if the cost of the equipment were reduced to the point where it were more attractive to the purchaser.

The Hickman household still has not quite reached that stage yet, and Dr. Hickman is working with the program on developing larger stills. I believe that he has here something that would meet that purpose, too.

Mr. INDRITZ. Have you made any special efforts to assist manufacturers of such products to lower their construction costs and to produce them on a commercial basis?

Mr. JENKINS. No, sir, we have not.

Mr. INDRITZ. Have you felt that is outside of the scope of your act?

Mr. JENKINS. We think that is a private market problem. Perhaps some kind of a study as to how it might be gone about would be a function of our office, but I do not visualize subsidizations for that purpose as a function of Government research and development.

Mr. INDRITZ. Would it be helpful to manufacturers of water conversion equipment to provide them with surveys of the market needs and the saline water resources so that they will have an idea of where they might market their products, and thus get them more interested in the program?

Mr. JENKINS. Yes, sir; we have thought so. Many potential manufacturers have come to us and have asked what is the potential market for this equipment and such market surveys, specific market surveys, simply have not been made.

We have considered making them. We have planned to make them. Our funds have not been quite enough to actually let contracts for that purpose yet. At the present moment, one of the Appropriations Committees has recommended that we do not expend funds for that purpose.

Mr. INDRITZ. Mr. Jenkins, what research has been jointly undertaken by the Office of Saline Water and the Department of Defense?

Mr. JENKINS. There has been no actual joint project in which the Department of Defense would, for example, pay a portion of the

cost and the Department of the Interior a portion of the cost. However, in all of our work, we have invited the Department of Defense technical people in to advise with us, and they have accepted those invitations.

We have met regularly with the Department of Defense. We have formal cooperation, representatives of each one of the armed services. Where we have interest in its field, we attend those meetings. We exchange complete information on what each is doing, and we offer at each time the choice of cooperating on any of the work that either of us has underway.

There has been some specific cooperation at the plant level; for example, down at the International Nickel Co.'s Harbor Island test station, the Department of Defense has 1 or 2 pieces of conversion equipment there and we have 2. There is actual cooperation at the working level there.

Mr. INDRITZ. Has the Defense Department asked you for any information on which to proceed with any research and development project in the field of saline water?

Mr. JENKINS. Yes. For example, in the development of the Hickman still, we have turned over all of our information to the Department of Defense that they have asked for.

They have visited our experimental work at Boston.

Then in connection with the cooperative work, we have worked with the Department of Defense on the Ionics process. We have held coordination meetings with others who are working with the Ionics group, and have invited the Department of Defense into those meetings, actually made an inspection and had all-day meetings discussing the technical scientific aspects and how to improve the work.

Mr. INDRITZ. In the U. S. News & World Report for March 8, 1957, on page 116, in an article entitled: "For Water Shortage—Relief From the Sea," there appeared a statement to the effect that the Navy Department, when first contacted by your Office with respect to the question of work on distillation processes, had indicated that the distillation processes needed no further research and that as a result—and I now quote from the magazine article—"Distillation experiments were put off for a year and a half."

Would you comment on the statement that the distillation experiments were delayed for a year and a half as a result of that advice by the Navy?

Mr. JENKINS. I do not have much comment to make on that. That is a news article.

In the beginning of the saline water program, Mr. Chairman, there was a canvass made of those who were working in this field and at that time it was felt that the Navy had had the work in distillation pretty well in hand. There were no radical new ideas proposed. And for that reason, we felt that it was better until some new ideas were proposed, that we expend our energies and funds in other directions.

Mr. JONES. You mean other than distillation?

Mr. JENKINS. Yes, sir. And then after about a year and a half, I think it was, Kenneth Hickman, who came forward with the first brandnew idea—no, it was Yale University which made up a proposal for examining factors connected with distillation. We went in to them.

Mr. JONES. Were you satisfied, Mr. Jenkins, that the Navy Department had the last word in distillation still for the removal of salt in water?

Mr. JENKINS. The Navy Department has certainly done a wonderful job over the years in obtaining distillation equipment for its particular use.

Mr. JONES. Yes. Were you satisfied with it, as far as your tasks were concerned under Public Law 448 of the 82d Congress?

Mr. JENKINS. Not at the present time. We feel there are many improvements that can be made in land-based equipment.

Mr. JONES. Had you made some improvement since the Navy declared itself not to be interested in further experimentation or research in distillation process?

Mr. JENKINS. I did not mean to imply that the Navy actually declared itself not interested in this. We decided that the Navy had the matter well enough in hand at the time; that until some new improvements came along, we weren't justified in going into it.

We believe now, yes, sir, that we have a number of very outstanding improvements in distillation work, both under the program of the Interior Department and——

Mr. JONES. Are they using any of your distillation processes now, the Department of the Navy?

Mr. JENKINS. No, sir; not in actual practice so far.

Mr. JONES. They are fully aware of what you have been able to accomplish in distillation?

Mr. JENKINS. Yes, sir.

Mr. JONES. And the matter has been a subject of discussion and formal communication between the Department of the Navy and the Office of Saline Water?

Mr. JENKINS. Well, I believe, Mr. Indritz, that you are assuming that I said that; are you not?

Mr. INDRITZ. Well, when you testified at the hearings on January 22, 1957, before a subcommittee of the Committee on Appropriations, House of Representatives, 85th Congress, 1st session, on the Department of Interior and related agencies appropriations for 1958 fiscal year, you stated, on page 42:

> In the beginning, we were advised by the Navy the distillation processes were about as good as could be made and we need not work on the distillation processes any longer.

So I gather from the statement you made then and from the news article I referred to, of March 8, which said:

> The Navy said that the distillation processes then used were good and that further research then would be a waste of time—

I gather this was a result of advice from the Navy.

Mr. JENKINS. I think that statement should have read, but did not in the transcript, that we were advised by the Navy, by one man in the Navy who was in charge of that work at that time, that the work had gone along about as well as it could and what was needed at that time was not further research and development but building of some large plants far beyond the scope of our program.

Mr. JENKINS. Yes, sir; we have these meetings from time to time. We have one scheduled for May 2 now.

Mr. JONES. And you feel you are expressing the statement of general accord between your office and the Navy Department or other agencies of the Department of Defense?

Mr. JENKINS. I feel very much that way, Congressman Jones.

I have expressed and the people from the Department of Defense have also said that they feel that this cooperation is among the most productive and pleasant that either of us has.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. Do you recall why it was that the Navy then advised you that no further research was necessary on the distillation process?

Mr. JENKINS. I thought I tried to straighten that out. But it was not advice that the Navy said that we should not do something. We had understood that the Navy had the matter pretty well in hand and decided we should not spend our money until something new came along.

Mr. JONES. Does the Department of Defense send you much money over there to spend?

Mr. JENKINS. Over to the Navy?

Mr. JONES. Over to you.

Mr. JONES. You do not have any exchange account, do you?

Mr. JENKINS. No, sir.

Mr. INDRITZ. As I understand you, however, you had received advice from the Navy Department that they felt it would be a waste of time to work further on the distillation processes?

Mr. PERLMAN. That is what Mr. Jenkins assumed.

Mr. JONES. It is an assumption of Mr. Jenkins?

Mr. JONES. The purpose of that inquiry, Mr. Jenkins, is to find out whether the expressions of dissatisfaction about the progress of the entire program, whether that was the foundation; and if it is, what we can do to help you get it back on the track again. This is the reason we are trying to track down if there were delays, and what occasioned them.

Mr. JENKINS. This matter of working in the beginning on distillation processes was expressed I think in several of our reports in this way, that distillation processes at that time and those proposed, even if operating without fuel costs, would produce water at far above our goals. And therefore we should concentrate our work toward processes that gave promise of much greater reduction of costs.

Now, this, as you will recall I am sure, was a very small program in the beginning. The first year we had $175,000. And to develop a distillation plant of some kind might have exceeded that cost many times over. However, as soon as the first proposal came to us for improvement of distillation processes that seemed to offer promise of real improvement, we went into that.

(Mr. Jenkins subsequently provided the following information:)

Our contacts with the Navy in the beginning were principally with one civilian employee in the Bureau of Ships who subsequently has retired. It was his personal opinion that the work conducted by the Navy up to that time on distillation was excellent, and that the processes were about as good as could be made. It was his feeling, expressed a number of times, that the best way to go about our program was to build large plants immediately, and that costs could be reduced best by improvement in large installations. We felt that research should come first. These were honest differences of professional opinion and when the program had reached a point that it was possible to examine more closely the

factors which might be improved by basic and exploratory research especially on land based units as contrasted with the shipboard units, that was done. We now have most satisfactory relationships and interchange of ideas and experiences with the Navy and other branches of the Department of Defense.

Mr. INDRITZ. In addition to receiving proposals for research projects from interested persons, does the Office of Saline Water make any effort to seek out likely firms or industrial companies that might be persuaded to engage in such projects?

Mr. JENKINS. Yes, Mr. Indritz, to the extent that we have had personnel for that purpose. Several of our technical personnel made what we call missionary trips for exactly that purpose and have contacted a number of research institutions, universities, have given talks and explained what we are doing. Dr. Gillam and Mr. Strobel have both carried on quite a bit of that work to try to get people interested.

Mr. INDRITZ. Has that been a fruitful endeavor?

Mr. JENKINS. It has resulted in some good technical proposals. I am not sure that we have gone into one as a direct result of that missionary work yet. We have not carried on nearly as much of this missionary work as we should because we have not had the staff.

Mr. INDRITZ. You have not had the staff to carry on sufficient work in that field?

Mr. JENKINS. That is right. There is enough work right in Washington to keep all of our people there all the time. There is enough work in the field to keep all of them there most of the time.

Mr. JONES. Mr. Jenkins, why is it you do not use your advisory committee and consultants to make these visual inspections of these projects and be appointed as missionaries in the field to incite the interest and desire on the part of these scientists and institutions and companies to go into the field?

Mr. JENKINS. There has been a little of this. One or two of the advisers have done some missionary work in this field. Dr. Koenig has.

Mr. JONES. Not too long ago there was testimony before another subcommittee of the Committee on Government Operations by Dr. Bronk, chairman of the National Science Board and president of the National Academy of Sciences, and Dr. Waterman, director of the National Science Foundation. Both were of the opinion that the use of their board was doing a great deal to promote interest in the fields of scientific inquiry. The selectivity processes that went into analyzing the potentials of the projects have given them great encouragement for the future from what they have been able to accomplish. The National Science Foundation and the National Academy accomplish a great deal by making good use of the various advisory committees that they have set up.

It would not be too expensive administratively to get your Advisory Committee and consultants a little bit more active; would it?

Mr. JENKINS. No, sir, it would not. And I want to say I think it is a good idea. I think that we would do well to put your suggestion into effect.

As Secretary Aandahl mentioned this morning, this particular committee is an advisory group to the Secretary of the Interior and they are rather high-level people.

Mr. JONES. Yes.

Mr. JENKINS. There are several college presidents. But we have also, Congressman Jones, 40 or 50 more of these consultants and some of them could do a good job at this. We could probably give them a small consulting project for some work of this kind. I think it would be an excellent thing to do.

Mr. JONES. Well, I think Dr. Waterman said that they were using funds for that purpose, and certainly it seems like a wise and prudent use for Federal funds to get the better minds interested in the problem. Because if we can, I am sure that this program will take on greater national prominence and we'll obtain better results from our investigations and inquiry.

The problem of research is trying to get people who have the abilities to put their energies and their mental capacity to the task of achievement. And certainly if they are not given the opportunity, we are not going to be surrounded or be accompanied with that kind of excellent mind that we want to appropriate to the problem. But you are far more experienced than I, Mr. Jenkins, and so I was just thinking out loud.

You go right ahead, Mr. Indritz.

Mr. INDRITZ. One of the letters that we received from interested persons, the Flakice Corp., I think, mentioned that it might be helpful to the program if more small companies were brought into it.

I wonder if you would comment on that suggestion?

Mr. JENKINS. If more small companies——

Mr. INDRITZ. That was the comment made in the communication we received, and it implies that the contracting or consulting program of the Office of Saline Water is devoted solely to the larger ones.

I wonder if you would care to comment on that point?

Mr. JENKINS. Well, I do not quite understand the implication in that communication which you received, because a considerable portion of our work has been devoted to small organizations, small consulting engineering organizations. I think that possibly because some of the larger organizations have been in development of hardware that has reached news outlets, that there are some who might naturally seem to feel that this is all that has been done, not knowing of our other efforts with the smaller people. We have many contracts with small organizations and individuals.

Mr. INDRITZ. You would welcome research work in this field by both the small ones as well as the large ones?

Mr. JENKINS. We not only would, but we do.

Mr. INDRITZ. One of the major problems we understand you have in connection with distillation plants is the problem of scale.

What is the status of the research work that is going on now in trying to meet that problem?

Mr. JENKINS. Mr. Indritz, I would like to refer that question to Dr. Gillam if I may. He will be giving some testimony. Also Mr. Cywin will be giving some testimony.

Mr. INDRITZ. We will let it go until later then.

Could you tell us why the RCA thermoelectric proposal was rejected?

Mr. JENKINS. Yes. We could not see a direct application any time in the near future to the thermal electric development that they had

in mind. This was taken up with—again here with the Department of Defense, and the proposal was referred to both of us. We simply could not foresee anything practical at the present time until RCA had gone further, if they do, with developing electric thermal components they have been working on in connection with refrigeration.

Now, here again, this is a highly technical subject, and I would like Dr. Gillam to comment on it if you would like to get into the technical aspects of it.

Mr. INDRITZ. Do you feel that the time has come yet for construction of larger size solar plants to get more accurate information as to the costs of construction, maintenance and operation, and other problems associated with solar distillation?

Mr. JENKINS. No doubt it has. We planned one larger solar still last spring and this was one place where we advertised for bids for construction. You asked earlier if we had any contracts that had been made as a result of bids. We do not have any contracts because we did not build that still, but we did advertise once. The bids were about twice what we had expected and we did not have the money in last year's appropriation.

Then we thought we would build that still this year, but when our funds were cut back from $1,159,000 to $725,000, we felt that we should not go ahead with it. Instead, we are building a number of medium-sized solar stills for comparative purposes, and I think we may obtain more data this way even than building the one still which we had in mind. At least it is a good intermediate step with our budget what it is now.

Mr. INDRITZ. If the proposed supplemental request that the Secretary is going to make for an additional $500,000 is granted by Congress, would the solar still that you have just been speaking about be one of those that would be included in that $500,000?

Mr. JENKINS. On that, Mr. Indritz, I think I will have to defer answer to that question until our budget is sent to the Appropriations Committee, will I not, Mr. Chairman? As to just what we are going to ask for in a supplemental appropriation?

Mr. JONES. You mean defer——

Mr. JENKINS. Yes.

Mr. JONES. I think that can be saved. And I believe it is the policy of the executive branch to withhold that amount until the disclosures have been made to the Appropriations Committee.

Mr. JENKINS. That is my understanding.

Mr. JONES. Yes, yes.

Mr. INDRITZ. In connection with the projects which you are working with down in North Carolina, you recently indicated you have a plant under design that might be capable of producing a million gallons of water per day. Which process did you have in mind when you made that statement?

Mr. JENKINS. I think my statement was not quite clear. I believe that we said that we were ready to begin designs. We do not have it under design at the present time.

Mr. INDRITZ. In the hearings before the Senate committee 3 weeks ago—Senate Appropriations Committee, on March 26—you were asked

whether you had anything tangible that you were going to achieve; and your response was, and I quote:

> We feel we are working toward that goal. We want to push each one of these projects as fast as we can. That is what we have in North Carolina, two projects approaching that stage now, and we expect to have a plant under design in the near future that will be capable of producing 1 million gallons of water a day.

Which of the projects did you have reference to?

Mr. JENKINS. This is the process known as the W. L. Badger, a long tube, vertical distillation.

Mr. INDRITZ. Would that depend upon your solving the scale problem?

Mr. JENKINS. Design can begin even before the scale problem is completely solved because we know that we can control the scale down at the lower temperature stages, and considerable work can be done in the beginning stages of design concurrently with our scale tests. Now, if it is necessary, it can begin. We need not handle all of this work successively; we can carry on some concurrently.

Mr. INDRITZ. How many professional people do you have on your staff?

Mr. JENKINS. Six, including myself.

Mr. INDRITZ. Does your staff put in much overtime?

Mr. JENKINS. Yes, they put in quite a bit of overtime.

Mr. JONES. I believe you have a vote of confidence all the way down the line, Mr. Jenkins.

Mr. INDRITZ. That is in connection with the present program you are now working on?

Mr. JENKINS. Yes, sir.

Mr. INDRITZ. With the additional work that would be entailed as a result of the extra $500,000 worth of projects that may come up under the supplemental appropriation act that the Secretary proposes, would you have enough personnel and staff to handle that?

Mr. JENKINS. At the present time?

Mr. INDRITZ. Yes.

Mr. JENKINS. Definitely no.

Mr. INDRITZ. Have you had any difficulty in hiring qualified people?

Mr. JENKINS. Yes, sir, we have. We have one vacancy now. I have enough funds in the present appropriation for this year so I could take on one more man. I would like to have him.

Mr. INDRITZ. Do you think if you had additional staff, your operation would be more efficient, more productive?

Mr. JENKINS. Yes, sir. Surely. We have not been able to recruit at the grades that we have, and this I think is rather common in the Government in scientific work.

Mr. INDRITZ. And with the insufficient staff that you have, you operate on a less efficient basis than you would if you had more?

Mr. JENKINS. Yes, sir.

Mr. INDRITZ. Mr. Jenkins, how many times have you or your staff or any member of your staff, discussed the saline-water program with Secretary of the Interior Seaton?

Mr. JENKINS. I do not know about the other gentlemen. I believe you said "or members of my staff."

Mr. INDRITZ. You or members of your staff.

Mr. JENKINS. I do not see any nods from my staff indicating that anyone has discussed it with Secretary Seaton so I expect that I am the only one who has met with him.

Mr. INDRITZ. How many times have you met with him, Mr. Jenkins?

Mr. JENKINS. Well, you see, Mr. Indritz, I work directly with Mr. Aandahl, Assistant Secretary. I meet with Mr. Aandahl often; in fact, quite frequently.

Mr. INDRITZ. But you have not discussed this with Mr. Seaton at all then?

Mr. JENKINS. I met with him once last August; with Mr. Aandahl when I first was introduced to Secretary Seaton.

Mr. INDRITZ. That is the only time you have discussed the problem with Mr. Seaton?

Mr. JENKINS. Well, at the advisory meeting recently, there was a luncheon for the advisers; I attended that luncheon.

Mr. INDRITZ. Do you or members of your staff prepare the press releases that are issued by the Interior Department on the Office of Saline Water program?

Mr. JENKINS. At the present time, and since about last November we have been assisting in the preparation of those press releases.

Mr. INDRITZ. Prior to November, you did not?

Mr. JENKINS. It depends on what those press releases were about. If they were Office of Saline Water press releases, we prepared them. If they were general press releases on the activities of the Department, which just included something about saline water, we did not prepare them, of course.

Mr. INDRITZ. Were those submitted to your office for review as to the saline-water aspects before they were released?

Mr. JENKINS. I am sure that some were. I am not sure that all were. I would have to check that.

Mr. INDRITZ. Were some of the discussions in those press releases unduly optimistic?

Mr. JENKINS I beg your pardon?

Mr. INDRITZ. Were some of the press releases issued prior to November of an unduly optimistic nature in terms of the economical cost that could be achieved or how near the program would be to its objectives?

Mr. JENKINS. I would not want to say that anything that was issued was unduly optimistic. A certain degree of optimism I think is inherent in what we are doing.

Mr. KNOX. Mr. Indritz, would you yield?

Mr. INDRITZ. Yes.

Mr. KNOX. I believe in order that we may clear up the record so there will be no misunderstanding, Mr. Jenkins, is Assistant Secretary Aandahl in charge of the saline-water project?

Mr. JENKINS Yes, sir.

Mr. KNOX. In other words, it is not necessary, then, that you meet with Secretary Seaton on the subject matter because it is under the jurisdiction of Mr. Aandahl; is that right?

Mr. JENKINS Yes, sir.

Mr. KNOX. And he is the coordinator between your department and the Secretary?

Mr. JENKINS. Yes, sir.

Mr. INDRITZ. Mr. Jenkins, when you receive a report prepared by a contractor, how do you evaluate the report? I am talking about the mechanics of it. Do you do it only with your own staff or do you have consultants evaluate it? How do you evaluate the report when it comes in?

Mr. JENKINS. I went into that considerably this morning if you recall in response to a question by Congressman Knox. But carrying on from that point, if you like, or I can repeat that, the proposal is received first in the Office of Saline Water and is referred to the specialist in that particular field. If there is any doubt, it is referred to me and I decide which is the specialist, and he consults with the others as is necessary and determines essentially whether the proposal has scientific feasibility, technical feasibility. Many do not, of course. Then if it does, that proposal is referred, to from 2 to 6 of our outside consultants.

They have a set of responsibilities, including evaluation of the technical feasibility, evaluation of the technical capabilities of the people proposing the work, the evaluation of the costs being proposed for the research, and the significance in the saline-water program. They give us that report essentially.

Then those evaluations are received. They differ somewhat. They are not all exactly alike, of course. Our staff then takes up the suggestions and comments and criticisms with the original proposer. We negotiate back and forth with them as to whether they wish to make changes in accordance with these recommendations of the outside specialists and our own staff as well.

If they do and if the proposal seems to be a feasible undertaking, one for which we have funds, we begin a contract negotiation. At that stage a considerable number of problems have already been negotiated through this correspondence. Nevertheless, there may be quite a lot of additional negotiations at that time. Those negotiations may be in correspondence or they may require face-to-face meetings.

Mr. INDRITZ. Do you have sufficient number of consultants working on it so you can guard against the possibility that any particular evaluator might have a special interest in a piece of equipment which might be manufactured, and thus avoid the bias which might result from such interest?

Mr. JENKINS. Yes. Yes, sir.

Mr. INDRITZ. Among the comments of the several committees at the Saline Water Symposium, there was one particular criticism mentioned by the Committee on Membrane Processes that it took too long for the Office of Saline Water to accept or reject proposals. Would you tell us how long it takes for proposals that come before you to be examined and acted upon?

Mr. JENKINS. At the present time, the average is—this is an average now—from about 1 to 3 months. Occasionally, there is a proposal that may require a little longer than that. And then, of course, sometimes there is a delay after an evaluation, waiting for funds.

Mr. INDRITZ. Is some of that delay due to the fact that you must correspond with your consultants who are evaluating the proposals?

Mr. JENKINS. Yes: that requires time.

Mr. INDRITZ. Couldn't that delay be lessened or eliminated if you had more personnel in your Office qualified to evaluate projects that are proposed?

Mr. JENKINS. We should have more staff. However, I rather like this method of having outside evaluators for this reason: We are able to draw upon about 60 of the country's capable specialists in these various fields. They only work occasionally for us, and are busy on their regular work, otherwise. Now, it would be mighty difficult to obtain all of that technical ability in our Office.

Mr. INDRITZ. But some of the evaluation aspects could be done by people in your Office if you had more personnel?

Mr. JENKINS. Not only could be done, but quite a bit is done now. Furthermore, if there is a difference of opinion among the evaluators, someone in our Office has to evaluate the evaluations.

Mr. KNOX. Could I ask a question?

Mr. JONES. Yes, sir, Mr. Knox.

Mr. KNOX. Mr. Jenkins, I believe you testified previously that you had a vacancy on your staff and you were unable to fill the vacancy with a competent individual because there was none available. Now, if it were not for these sixty-odd evaluators on the outside who had great knowledge of the program, how did you expect to do it in your office?

Mr. JENKINS. Oh, I did not mean to imply, Congressman Knox, that we would expect to do all of that work that the 60 do in the office. It is just that, if we had a few more people in the office, we could do a better job of coordinating these other activities.

Mr. KNOX. Approximately what would the increase in staff be in your office in order to do all of the work within the Department instead of using outside evaluators?

Mr. JENKINS. I have not made an estimate of that. However, we made up an outline of the staff which we felt was ideal within the total amount of the limitation and the present authorization, and that amounts to about 20 people.

Mr. KNOX. What would be the additional cost of the operation of your office if you had 20 additional people to fill these positions?

Mr. JENKINS. With their expenses, we have $125,000 for all administrative expenses this year.

Mr. STROBEL. Excuse me. Did you say 20 additional? Mr. Jenkins was speaking of 20 total in the office.

Mr. KNOX. I did not mention any figure, just what he said.

Mr. STROBEL. He meant total. I heard the word "additional."

Mr. KNOX. I used the word "additional"; that is for sure.

Mr. STROBEL. He was talking about 20 total, not additional.

Mr. JENKINS. The total we had planned for the staff, under the present limitations, would be 20 people.

Mr. KNOX. You now have six?

Mr. JENKINS. We have six professional people and——

Mr. KNOX. Are you speaking of professional people or of the combined staff?

Mr. JENKINS. Combined staff.

Mr. KNOX. And you have 14 on your staff?

Mr. JENKINS. Yes.

Mr. KNOX. Then you would add only an additional six; is that right?

Mr. JENKINS. Yes, sir.

Mr. KNOX. What would be the approximate cost of adding the additional six?

Mr. JENKINS. That would be about $75,000, altogether.

Mr. KNOX. About $75,000. And what are you paying the sixty-odd individuals on the outside who have been doing the evaluating for you? Approximately.

Mr. JENKINS. They have been receiving about $10,000 a year. We would continue under this arrangement, Congressman Knox, even with the 20 people, to continue the people on the outside. We would not do away with their services just because we have the 20 people in our office. To handle all of the evaluations, all of the scientific work, within the Government, we would need a much larger staff than is authorized at the present time.

Mr. KNOX. And you anticipate that, if you could get the Congress to appropriate the funds, you could recruit the staff.

Mr. JENKINS. Such a staff as might be authorized?

Mr. KNOX. We are speaking now of technical people, such as engineers and scientists.

Mr. JENKINS. It is difficult to recruit technical people.

Mr. JONES. He testified earlier he has had a vacancy in his office for a long time and has not been able to find anybody to fill the available space.

Mr. KNOX. I was present, Mr. Chairman. I was wondering how do you expect to fill 6 additional vacancies when you are not able to fill 1 that now exists, if the vacancies were to be filled?

Mr. JENKINS. One answer to that is, during the past 4 or 5 months that I have had that vacancy, I have been trying to find 1 man who is a superman to fill the place of the 6 I need. I have not been able to find him because I have, perhaps, expected too much of one man.

The workload is pretty heavy in our office, and most people know that.

Mr. KNOX. My interest is to see that you have the proper staffing so this program can go forward, and that was the reason for the inquiry. I had thought, from your testimony, that you were using these outside people because of not having the technical staff available in order to do the job in the Department. Now, I understand your testimony to be you would still continue the 60 on the outside, to call upon them when it is necessary, plus the additional 6 technical people you desire.

Mr. JENKINS. Yes, sir.

Mr. KNOX. I think that clears it up.

Mr. JONES. Now, do you have any more general questions?

Mr. INDRITZ. Yes.

Mr. JONES. All right.

Mr. INDRITZ. Mr. Jenkins, could you tell us what processes have been field tested under actual operating conditions rather than merely laboratory tests?

Mr. JENKINS. One, electrodialysis process, that of Ionics, Inc., was field tested in Arizona on brackish water and in South Dakota on a different type of brackish water.

Mr. INDRITZ. Were the results of those field tests compatible with the cost projections based on laboratory tests, or did they indicate the costs were much higher than the laboratory test had shown?

Mr. JENKINS. The latter is true, Mr. Indritz. The costs were shown to be substantially higher than had been estimated from laboratory tests. This is quite often the case.

Mr. INDRITZ. Would that indicate the importance of having field testing of each of these processes, rather than relying simply on extrapolation of costs based on laboratory tests?

Mr. JENKINS. Definitely.

Mr. INDRITZ. Would you tell us how much higher they were?

Were they double? Triple? Six times?

Mr. JENKINS. I would have to get that for the record for this reason, there were early estimates on small laboratory equipment, there were larger estimates on larger laboratory equipment. To answer your question, I would have somehow to find, perhaps from the firm, what its latest estimates were on the basis of laboratory equipment just before the field tests were made. I do not think I have that.

Mr. INDRITZ. Could you provide for the record what the laboratory tests estimates were, just before the field tests, and what the actual costs were on the basis of the field tests? Could you provide that for the record?

Mr. JENKINS. Yes.

(Subsequently, the Office of Saline Water provided the following statement:)

No laboratory estimates of cost just prior to the field test seem to be available. The standard cost estimating procedure was developed in 1956, 2 years after the laboratory estimates were made in 1954. Therefore, comparisons of the two costs cannot be precise. However, Ionics' 1954 estimated cost of converting a 4,000 parts per million water in a 75-million gallon plant, based on laboratory data and certain assumptions was 6 cents per thousand gallons, as shown in table 6.4a Research and Development Progress Report No. 1. The firm's estimated cost for a comparable plant based upon information obtained from the field tests and future improvements, using the same assumptions, was 22 cents, and by the standard cost estimating procedure was 41 cents. Both of the latter two estimates are shown in table 7, Research and Development Report No. 11, which contains the results of the field tests.

Mr. KNOX. On that point, I wonder, Mr. Jenkins, if you would tell us as to how you determine costs in the field?

Now, is that including all of the experimental work, the construction and putting the plant into operation, and having to make certain changes in order to get it to function properly? Or just what is used in determining the field test expense?

Mr. JENKINS. Oh, there are two questions here, Congressman Knox. One is the expense of conducting field tests, and the other would be the cost of the water that would be produced by the equipment. Now, I am not quite sure from your question which one you are asking me for.

Mr. KNOX. What I am interested in is to determine why your field tests should far exceed the laboratory tests.

Now, there must be something in the field that is being done that possibly has not been brought into overall operations within the laboratory. It is difficult for me to understand why it is that you just move from one place to the other and you have a considerable increase in cost, unless it is the fact that due to the construction, the size—possibly where the operation does not properly function, and then plus the fact that possibly you have to go in and make major changes; what is it?

Mr. JENKINS. Well, I think all three of those factors that you mentioned. Major changes found in the field are necessary. Not all of the costs can be foreseen. You find you have to have another pump here,

another valve there. You possibly could not foresee everything in the laboratory where you do not know the actual field conditions.

In addition, in this one case we found there was some formation of the scale, again, that we talked about, in the evaporation equipment, and means had to be worked out for overcoming that scale. That is one thing that did not add too much to the cost. We controlled scale. It costs quite a little to learn how, but it would not add too much to the cost of the water.

Mr. KNOX. Well, can you effectively determine your cost through pilot plants without going into a large operation? That is, to determine actual costs?

Mr. JENKINS. Well, there are certain things that can be determined in glassware size and certain things that can be determined on the bench, and then other problems that can be determined in the field that are not disclosed in either. And then when we get into larger pilot plants, there are certain factors that have to be worked out there.

May I give an example. Quite a number of years ago in connection with the Ionics work, we made a study of the possibility of demineralizing some brackish water in a reservoir in South Dakota. The water there was only slightly excessive in salinity for irrigation use on that particular soil, and therefore a great demineralization was not needed. But to handle that volume of water, it was estimated by Ionics that we would need some 8,000 of these small demineralization units if I recall the number correctly.

Now, there were I believe 2 brass gate valves in connection with each 1, and that made about 16,000 valves at a cost of about $10 each, and even that cost was pretty high.

Now, we had a problem which was not met in smaller installations. Here we would have a bank of 8,000 units, with 300 volt direct current, all around the building. Salt water also around the building. And just the electrical, hydraulic and civil engineering problem of handling something like that, is a problem that would have to be met at some time if a large plant like that were built. We would learn a lot from it. It is not necessary to conduct it now in order to improve the individual unit.

Mr. KNOX. Now is the project developed to a point where there is justification for setting up a plant that would produce a million gallons of fresh water a day?

I raise that point, Mr. Jenkins, because I believe you mentioned that this one plant would produce a million gallons and I believe, if I recall your testimony, this plant was to be constructed in North Carolina; was it?

Mr. JENKINS. I am sorry, if I said that the testimony should be corrected. There was some misstatement there. We do not plan to build a million-gallon plant in North Carolina.

Mr. KNOX. I was wondering. You mentioned the plant, that the byproduct, that is the brine, that is the problem inland.

Mr. JENKINS Yes.

Mr. KNOX. Therefore, if there was going to be any project, should it not be built by the sea where the brine can be returned to the sea so you will not be confronted with the problem?

Mr. JENKINS. Yes, sir. This would be done. This particular plant that we have in mind is adaptable for use on the sea water, and we

have in mind applying it to conversion of sea water. Certainly such a pilot plant would be at the seashore. The only question was whether it would be built in North Carolina or some other part of the country.

Mr. KNOX. Yes. I had just taken from your testimony, that I thought you said North Carolina. Maybe I was wrong in recalling that you testified to that.

Mr. JENKINS. I am sorry if I did. I will correct that in the record. The pilot work that is underway at the present time at North Carolina, which Mr. Cywin will describe here shortly, is a test on 1 part of 1 unit for the purpose of solving 1 problem in scale formation. The plant that we have been talking about, a million-gallon plant that we are about ready to begin designs for, would undoubtedly not be built at that location in North Carolina.

Mr. KNOX. What is the estimated cost of this million-gallon plant?

Mr. JENKINS. That has estimated at about $1.25 million.

Mr. KNOX. And are you satisfied that the program is perfected to a point that there can be justification at this time to construct such a plant?

Mr. JENKINS. Well——

Mr. KNOX. And have water produced within the realm of the possibilities of the consuming public to purchase the water?

Mr. JENKINS. I am not quite ready to say that we are ready at this moment to recommend construction of that plant.

We are ready to begin designs, designs include a site selection among other things; and by the time that the designs were prepared or fairly well along, we should have the results of our scale test in North Carolina, and at that time I believe that construction would be justified; that is, on this one process.

Mr. KNOX. Yes. I believe I share the concern our chairman does relative to the research work, and so on, going on. We certainly want your opinion. I do hope we do not start on a crash program before we are actually ready, and waste the taxpayers' dollars, when it could be better spent in the field of research. So that when we launch this program, we are not going to have a white elephant on our shoulders which will possibly have to be dismantled and redesigned in order to do the job within the financial ability of the people that would be expected to use the water, to compensate the Government or the installation for the product which they are producing.

I raise that question as to whether or not you actually feel the program is far enough in advance today to justify going out and spending over a million dollars in construction of a plant to produce fresh water from sea water.

I should like to hear, Mr. Chairman, what is your deep-rooted concern over this project of launching a program of this magnitude.

Mr. JONES. Well, I can say, Mr. Knox, I do not believe at the moment I have an opinion of the proposition Mr. Jenkins is discussing.

However, I am vitally concerned with the long-range research program. If we get it out of balance by having this kind of activity, I know the enormous cost, and we will wind up with a program of pilot plants and plant operation and we will lose sight of the research program. And basically I think that is the more important of the two.

There is a place for both of them, I would say, Mr. Knox.

As I understand it now, on all the research and development activities of the Federal Government, we are spending about 60 percent for development and about 40 percent for basic research.

Now, we are confronted with a tremendous national problem not only for the security and defense of this country but simply to take care of the tremendous expansion and growth of this country, to provide greater scientific exploration, study and research. And if we neglect the basic research, then the development program will come to naught. It is simply a question of time.

It seems to me that we need to spend more of our money, more of our effort in basic research and have it in balance with the development programs so that we do not let one get ahead of the other.

I believe right now we can say definitely that as far as the national picture is concerned, basic research has been neglected. It has been neglected for the simple reason that when sputnik got up in the air, we all began to realize that technological advancements had not kept pace in the universities, where there should have been a stimulation of the young minds to go into the field of engineering and research and the different technical opportunities that a basic research program would afford.

And now we have come back, and the quality of our young minds is being reassayed as to how we are going to use them, how we are going to place them, and how ultimately we are going to have a national program of total utilization of our good scientific young people and their minds on a basic research program.

But I am not intending to lecture on that. That is an observation I am making. I just feel that we cannot neglect the basic researches.

I believe that a long-range program with saline water or any other program requiring basic research is going to require long-range plans, and a recruiting of young people right now should be commenced to get people interested in your program.

It can be done with the universities and the colleges throughout the country. It probably can be done a little bit cheaper that way. They are better equipped to take on those types of programs than the establishment of your own laboratories and facilities that you might erect. And I think that is true not only with Government but industry as well.

Mr. KNOX. Well, Mr. Chairman, I certainly share your views on the research problem, and at least personally I would not want to appear to be pressing for an installation for the production of fresh water at a great cost to the American people unless you people who are technical people and in the field and in charge of it are sure that your program is developed to a degree that it is going to be able to produce.

I think we certainly have that field of research and experiments in the field of pilot plants that will give us that assurance in the near future.

So I certainly am not in any way criticizing the Department for possibly not having a plant in operation which would serve the community at this particular time unless you are assured—and, of course, I would like to see it developed as soon as possible when you are assured, or reasonably assured I should say—that the time is here for the construction of the plant that will bring to this country an advance

in one of our great natural resources, which is our water, for the general public, whether it be for industry or private use.

I am deeply concerned about it because I think if we go off the deep end that possibly it will end up with a subsidy from the Federal Government to keep it in operation.

Mr. JONES. Well, I want to correct the record. I used a figure a minute ago of 60–40 percent, 60 in development and 40 for basic research. I was in error there. It is 8 percent for basic research, 40 percent for both applied and basic research, and 60 percent for the total of development programs in connection with scientific effort. So basic research receives a lot less than 40 percent; only 8 percent is spent on basic research.[5]

Now, Mr. Jenkins, do you have any information that you might have obtained through technical magazines and through other sources that would give you any idea of the programs that the Russians are carrying on at the present time comparable to the efforts of the Office of Saline Water?

Mr. JENKINS. We have a small amount of information about activities in this field in Soviet Russia. That information consists, first, of a book which was published in 1948 and which we have recently had translated. It is now available for distribution.

That showed that work in this field in 1948 in Soviet Russia and available to Soviet Russia was, I would say, fairly comparable with that in this country, although their book contains photographs and descriptions of British equipment and other equipment made elsewhere.

In addition, we have one other chapter that has been written on the subject of electrodialysis, and that is about the extent of our knowledge of developments in this field in Soviet Russia. We know that some work has been done in development of solar energy, and I believe that some of it is in connection with solar distillation.

This does not mean that we have not tried to obtain additional information, because we have, but we simply have not succeeded.

I met at an international meeting last summer, which was attended by a delegate from Soviet Russia, and I specifically requested information on this subject from him. I was assured that it would be sent to me. I have not seen it.

And one of the secretaries of the Russian Embassy called on us recently and obtained some of our published reports that are available to the public. He assured us that he would follow up and attempt to obtain information on what Soviet Russia is doing. We have not heard from him on that.

Mr. JONES. Mr. Jenkins, I wrote a letter to the State Department and on March 6 of this year I received a memorandum of published information that they had available of Soviet origin relative to saline water research programs. It commented on several types of programs that they were pursuing.[6]

Mr. JENKINS. May I ask a question?

Mr. JONES. Yes, sir.

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[5] Statement of Dr. Alan T. Waterman, Director, National Science Foundation, quoting from the Foundation's annual study "Federal Funds for Science," in hearings, p. 28, on research and development, before subcommittee of Committee on Government Operations, House of Representatives, 85th Cong., 2d sess., January 15, 1958.

[6] The State Department letter of March 6, 1958, appears in appendix A, item 3, p. 282.

Mr. JENKINS. Does that response relate to water in general or to saline water conversion?

Mr. JONES. Oh, saline water. These summarize technical papers published in 1956 and 1957. They are all Russian and Soviet collections.

Mr. JENKINS. There may have been some translations that have not come to our attention.

Mr. JONES. We shall submit them to you then, Mr. Jenkins.

Mr. JENKINS. I would be delighted to have them. Thank you.

Mr. JONES. Do you communicate with the State Department in order to keep up with these pamphlets and publications?

Mr. JENKINS. Yes, sir. We have liaison with the State Department in three areas. One, with an official liaison officer who is in the Division of Fuels. Then, in addition, we have a contact with the UNESCO relations staff. We also have contact with a group that has to do with scientific developments in Israel.

Mr. JONES. Well, I understand that the various departments of Government are going to accelerate the propagation of translations of technical papers uttered by the Russians, to make them available. And I am quite sure this is part of the State Department's endeavor to keep up with it. And I am sure that your liaison will help you to obtain those various things.

Are there any further questions?

Mr. INDRITZ. Could you inform the subcommittee, Mr. Jenkins, on the work being done on the membrane process in other foreign countries?

Mr. JENKINS. Yes, I could, or when Dr. Gillam discusses the membrane processes, perhaps he might. I think he is a little better informed on one than I am.

Mr. INDRITZ. We will leave that for Dr. Gillam.

Do you believe that the amount of work that your Office did in connection with the international symposium on saline water conversion was worth the effort?

Mr. JENKINS. Definitely, Mr. Indritz, it was worth the effort. It was, I think, looked upon as a high-level scientific symposium in which many people exchanged ideas, information on what they were doing, and, in addition, there was a set of recommendations as to what should be done in each 1 of the 4 major fields under discussion.

The symposium was certainly worth the effort. I am sorry that the purpose of the symposium was misunderstood in a few places and therefore there was——

Mr. JONES. What do you have particular reference to, Mr. Jenkins? Misunderstood?

Mr. JENKINS. The purpose of the symposium was to bring together our scientific contractors and others to exchange scientific ideas and information to help the research and development program advance. And it was not a program for demonstration of existing commercially available equipment. And that fact was not understood by everyone. As a result, there was some——

Mr. JONES. Were the manufacturers disappointed that they were not able to display? Is that part of it?

Mr. JENKINS. I think 1 or 2 were.

Mr. JONES. I see.

Mr. JENKINS. They did not understand the purpose of it, and we had——

Mr. JONES. That would be inherent in any kind of meeting—that somebody would be dissatisfied—would it not?

Mr. JENKINS. Yes, sir. But it was those 2 or 3 dissatisfactions that got into the press.

Mr. JONES. Did you not all pass a resolution that everybody had a good time?

Mr. JENKINS. Yes, sir. That resolution was passed——

Mr. JONES. Well, fine.

Mr. JENKINS. And sent to the Secretary.

Mr. JONES. Fine. That is good then. If you had a good resolution—every good convention has got to end with a resolution like that—I am sure that it will keep well.

Mr. INDRITZ. When will the papers that were read there be available?

Mr. JENKINS. I hope within another month. They are in the hands of the printer now. And the National Academy of Sciences has the responsibility for this. They are being published as one of their publications, so there are certain standards that must be adhered to. I expect they will be available within a month.

Mr. INDRITZ. Will they be widely distributed?

Mr. JENKINS. The Academy has the responsibility for distributing them. They will be available to everyone. There is a charge for them. They are public documents.

Mr. INDRITZ. As soon as they are ready, will you provide a copy for the subcommittee?

Mr. JENKINS. Yes, sir.

Mr. INDRITZ. Did Dr. Wegelin of the Netherlands TNO organization attend the symposium?

Mr. JENKINS. Yes, sir.

Mr. INDRITZ. Did he indicate that the TNO equipment was in advance of that of the United States in the membrane process, in terms of being able to produce water at lower cost?

Mr. JENKINS. Because of the much lower capital investment, capital costs.

Mr. INDRITZ. That is because they have cheaper membranes?

Mr. JENKINS. No, their process provides that the user may obtain his own membranes locally if necessary or from any commercial source. It is the equipment itself that is of lower cost.

For example, we have received quotations of about $17,000 for a piece of equipment without the membranes. We can buy the membranes in this country for about $4,000 or $5,000. And, in addition, there is an import duty of about $5,000, making about $27,000 for this particular piece of equipment. It is reported to have about the same demineralization capacity as equipment manufactured in this country for which the investment cost is about double this amount. The investment cost is reflected, then, in the cost of the water, and in that way one might say that Dutch equipment is cheaper.

Mr. INDRITZ. Was that the membrane process involved in the TNO research that the United States did not become a party to?

Mr. JENKINS. Yes. That is correct.

Mr. JONES. Is that all, Mr. Indritz?

Mr. INDRITZ. Yes, sir.

Mr. JONES. Now, Mr. Jenkins, do you have any particular order in which you would like to have your staff appear?

First, Mr. Romney I believe has a question or two he wants to ask.

Let me say this to the staff now. Gentlemen, I want to get through at 5 o'clock if we possibly can, and I want to give every witness a full opportunity. If the questions are going to be repetitious, then I will ask you to withhold them. Or if data and information are not available, I hope the witness will just request leave to file them at some subsequent time.

Mr. ROMNEY. Mr. Jenkins, on October 18, 1956, Secretary Seaton gave a speech at Chicago before the Audit Bureau of Circulation. A paragraph in that speech reads:

> In any event, I believe we can foresee the day when there will be networks of water pipelines crisscrossing this country in much the fashion that petroleum lines do today. They will be carrying water from where it is obtainable in one form or the other into those areas where it simply does not exist at all or in less than needed amounts.

On January 8, 1957, the Secretary gave a speech in Phoenix, Ariz., in which he incorporated a paragraph along similar lines.

On February 15, 1957, the Secretary gave a speech before the National Farm Institute at Des Moines, in which he incorporated similar language.

And then as late as October 14, 1957, in Chicago, the Secretary included language, on the order of that which I have read, in an address given by him before the Inland Daily Press Association.

Did you or anybody in your office write those portions of the speeches of Secretary Seaton dealing with the saline-water matter?

Mr. JENKINS. No, sir.

Mr. ROMNEY. Did you or anyone in your office have an opportunity to review those speeches with respect to the material on saline water conversion?

Mr. KNOX. Well, now, Mr. Chairman, I am just wondering if this is a fair manner in which to interrogate a civil-service employee of the Department as to whether he wrote the speech, whether he had an opportunity to review the speech. I think he is at the command of his superior, and I believe if we want to get that information, in all fairness, Mr. Chairman, that we should request Mr. Seaton to furnish it.

Mr. JONES. Mr. Romney, let me see what you are quoting the Secretary as having said.

Mr. ROMNEY. This paragraph right here, sir. And I have the speeches.

Mr KNOX. I do not want to do anything else but be objective, but I just doubt the good judgment and wisdom of requesting a civil-service employee to pass judgment upon the remarks that were made by the Secretary of the Interior when the Secretary of the Interior is available to come up and justify his own remarks as to who wrote them and as to what bases he used as a background.

Mr. JONES. Well, from the testimony that Mr. Jenkins has given us today and that of Assistant Secretary Aandahl, it is evident that if these quotes of Mr. Seaton's are correct, he was puffing his wares in his Chicago speech. And if Mr. Jenkins feels that his relationship between the Secretary and this utterance by the Secretary is of a confi-

dential nature, then I do not think that he should be called upon to say whether he prepared that statement or did not prepare it.

Now, as to whether or not he concurred in it will be a proper question, I would think.

Mr. KNOX. I do not object to asking Mr. Jenkins whether he concurs in it.

Mr. JONES. Well, I am sustaining the objection you raised to exclude the question as to whether or not he prepared the statement. Whether he prepared it or whether he didn't prepare it is of no consequence.

Mr. KNOX. It is immaterial.

Mr. JONES. The question is whether or not he believes that it is factually correct. And he does have an opinion as to the ultimate time in which we are going to have potable water running through conduits from city to city through the United States.

Mr. KNOX. If Mr. Romney would rephrase his question in that direction, I certainly would have no objection. But I just raise that question as to the propriety of asking——

Mr. JONES. The Chair has sustained the gentleman, Mr. Knox.

Now, do you want to ask him that question? If you do not, I will ask that question and get this whole thing in focus. If there is a belief on the part of the Secretary, and the Secretary is speaking for the Department of the Interior and the executive branch of the Government, that he is expecting potable water from brackish or salt water to be made available in the immediate future to be carried all over the country, do you think that is liable to happen any time soon?

Mr. JENKINS. It seems to me, Mr. Chairman, that I recall one statement of this kind in which there was included a qualification that by the end of the present century this might be foreseen.

Mr. JONES. Mr. Jenkins, let me hand you the statement and let you read it. Then I will ask you the question: Do you share the optimism of the Secretary's utterance on that date?

Now, that question is not to embarrass you, Mr. Jenkins, but to get your professional advice for the subcommittee as to whether or not you think there is a great optimism. Or do you think that they probably will not be carried out at the rate which the——

Mr. JENKINS. Well, I feel, Congressman Jones, that certainly there will be a time—how far in the future I do not know—when it will be necessary and possible to bring water from the seashore in pipelines to some distance inland. The distance, of course, will depend upon the economics. And as far as carrying that water——

Mr. JONES. Mr. Jenkins, let me see if I can give you some relief to the question.

According to your testimony at the hearings held before the Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs of the House of Representatives on March 8, 1957, 85th Congress, 1st session, you disassociated yourself from statements of a similar character.

Mr. JENKINS. I have that testimony.

Mr. JONES. That is on page 25 at the bottom of the page of those hearings.

Mr. JENKINS. I believe I was asked at that time if they—and I never was sure who "they" meant—had called upon me for this particular statement. And that gets back to your original question.

Now, as was stated at that time, you may notice that Assistant Secretary Aandahl undertook to reply to that question at that time because it had to do with matters at secretarial level. And he stated here on page 29 of those same hearings as follows:

**And I do not think that the statements that have come from the Secretary's Office which have been intended to be visionary and which have been intended to give some hope to the American people have gone far enough so that we need to be disturbed by their implications. In fact, I think that they are very constructive. I think that the American people need a touch of optimism.**

Mr. JONES. Yes.

Mr. JENKINS. From a technical standpoint I think I should say merely that there is to be water brought inland, undoubtedly. How far it will come and how far one person can foresee that day as contrasted with what another person can foresee may be quite different.

Mr. JONES. Yes, I understand.

Mr. JENKINS. If the Secretary can foresee that day——

Mr. JONES. I did not ask you now about what the Secretary could see, because that brings me back to just the objection I sustained from the gentleman from Michigan to saying what the Secretary could see. And I am trying to keep you out of occupying the Secretary's shoes and to let you pass on what I think is a note of optimism in the Secretary's statement.

I do not particularly want you to comment on the Secretary's statement as much as to have you comment on the fact of the rate at which this whole program will move forward, Mr. Jenkins.

Mr. JENKINS. I think that the rate that the program will move forward is dependent quite a lot on the magnitude of the activity, the rate at which new ideas and development of the present ideas can be pushed forward. And I hesitate to make a forecast in the future. Most professional people just do not like to forecast the future.

Mr. JONES. Mr. Jenkins, I believe I have read every public statement that has been printed that you have made, the technical papers that you have authored, and I did not detect in those papers that the Secretary in his statement in Chicago agreed with you about the progress.

So it is not the proposition of you being in accord with the Secretary, but I am going to say the Secretary is not quite in accord with you; is he?

Mr. JENKINS. I am glad you put it that way.

Mr. JONES. Yes. You do not think that we are ready for the breakthrough? You do not think that in any of the research projects now underway there is going to be an announcement in the immediate future that we are going to produce water for irrigation at about $40 an acre-foot; do you? I believe that is the figure you established as a reasonable cost on the highest cost factor.

Mr. JENKINS. Not for conversion of sea water in the immediate future. But for conversion of brackish waters I think we will have that in the near future.

Mr. JONES. Yes, sir. All right. Now, Mr. Jenkins, in which order would you like to have your other witnesses appear? Let me show you the list the way we have them here. Do you have a copy?

Mr. JENKINS. This is an excellent order.

Mr. JONES. Fine.

Mr. JENKINS. Dr. Gillam is in charge of the Branch of Research, where the research work begins.

Mr. JONES. Dr. Gillam, would you come up here, please?

Dr. GILLAM. Mr. Chairman, I have a few slides I would like to discuss later. If it is permissible, I would just as soon stand here so I can use the pointer.

Mr. JONES. Off the record.

(Discussion off the record.)

## STATEMENT OF DR. W. S. GILLAM, CHIEF, BRANCH OF RESEARCH, OFFICE OF SALINE WATER, DEPARTMENT OF THE INTERIOR

Dr. GILLAM. I will limit this discussion to a rather brief review of membrane processes, said processes differing from other conversion methods in several respects.

First of all, there is no change of phase in the membrane processes. By that I mean we do not heat or distill water. We do not freeze water to form ice and make pure water.

Secondly, membranes or some type of barriers are involved to screen out the salts or screen out the water, and finally most of these processes are designed to remove the salts from the solution rather than to remove the water.

Then, to get directly into a brief review of these processes, let me say this: The technical feasibility of several of these membrane processes has been demonstrated through research and development. At least one process appears to be economically feasible at present when applied to brackish waters and under certain conditions.

The membranes utilized in all of these processes can be conveniently divided into two groups. One, is an ion-permeable type, and the other is an ion-restraining type. We will try to make those differences a little clearer with the slides.

These processes, then, four in all, consist of the following:

First, electrodialysis, which was mentioned this morning. An electrodialysis cell consists of a sandwich of ion-permeable membranes to which an electric current is applied to cause separation of the ions.

No. 2 is the osmionic process, where the potential to drive ions through their respective ion-selective membranes is supplied by a concentration difference between the two solutions, the solution you are demineralizing and a brine.

The third is reverse osmosis, where sufficient pressure is applied to the saline water solution to force pure water through the ion-restraining membrane into the fresh-water side.

And, finally, the fourth one is transport depletion, which differs from electrodialysis in the nature of the zones or layers, known as controls, which correspond to the membranes, and all the controls are of the same character.

One of the limiting factors in all of these processes has been the membranes themselves. Consequently, a considerable amount of research has been conducted by organizations in this country and abroad toward developing or improving the characteristics of these membranes.

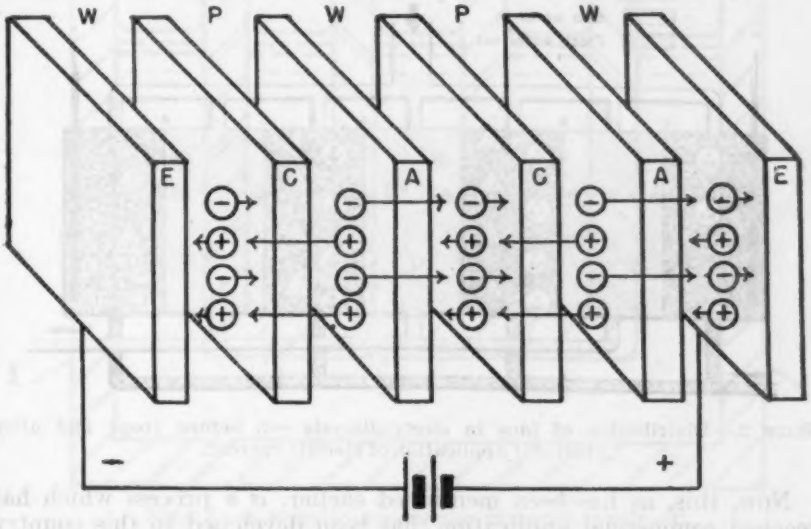
As a result, considerably improved membranes have been produced, and some of these are available today.

This is an extremely important fact when you stop to realize that the capital investment and membrane replacement in these processes constitutes a considerable portion of the total cost of converted water. So anything that can be done to decrease the energy and membrane replacement requirements by decreasing the resistance of the membranes, by making the membranes more durable, and by reducing the cost per unit area, will tend to reduce the cost of converted water.

Recently one company in this country has offered improved ion-permeable membranes in quantity, at a cost per unit area which is approximately one-fifth of what it was formerly. This development has been within the last 2 years.

The Office of Saline Water has conducted and is conducting some limited fundamental research on the improvement of both types of membrane, ion-permeable and ion-restraining. However, this field of endeavor—I mean by that the membrane improvement—appears to have reached a degree of maturity which dictates that the application of these membranes in electrodialysis equipment or the development of cells, improved cells or units, should receive more attention, and we hope to push this along in the coming years.

Now, if I may, I would just like to say a word, with the help of slides, about the principles involved, how these processes work, and try to show you the present status of these developments. Then, later, if there are questions, we shall attempt to answer them.



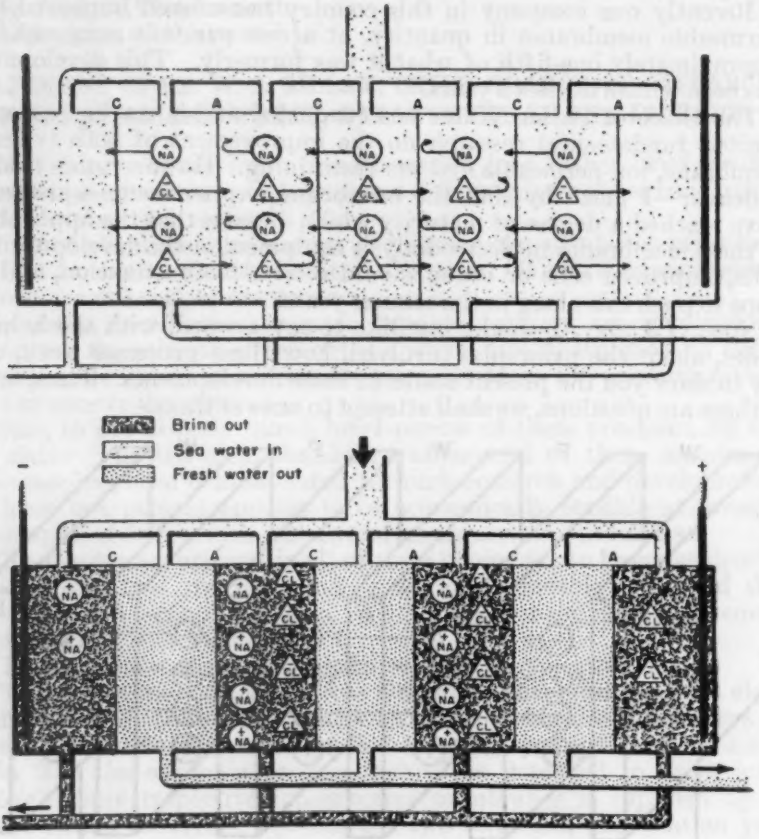

SLIDE 1.—Schematic arrangement of ion-selective membranes in an electrodialysis unit.

Running through these rather briefly, we have an example here (slide 1) of a schematic diagram of an electrodialysis unit in which we have a sandwich of alternating cation-permeable, (C) and anion-permeable (A) membranes in the unit.

When the electric current is applied, cations, that is, positive ions, pass through the one, anions, that is negative ions, through the other membrane.

Next slide.

Thus we have alternate compartments being depleted of salt while the intervening compartments are becoming enriched with salt, as shown on slide 2.




SLIDE 2.—Distribution of ions in electrodialysis cell before (top) and after (bottom) application of electric current.

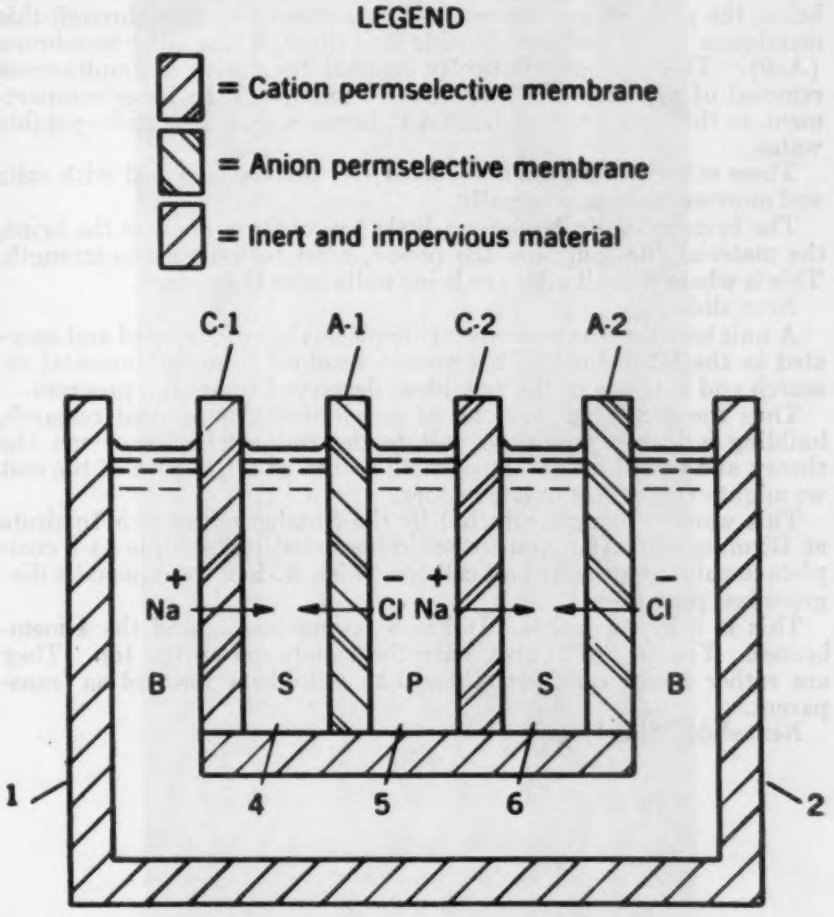
Now, this, as has been mentioned earlier, is a process which has reached commercial application, has been developed in this country and abroad, and there are several units—I would say 12 to 20 units—in operation throughout the world.

We may go into a little more detail on that in connection with some questions we might anticipate.

Next slide.

Process No. 2 which we mentioned was the osmionic. This differs from electrodialysis in that it does not require an outside electric current, nor does it require electrodes. The driving potential is furnished by the difference in concentration between a brine and the water you want to clean up or purify.

Incidentally, most of these membrane processes are concerned with brackish waters, at present.




SLIDE 3.—Schematic cross section of osmionic unit cell.

Slide 3 represents a schematic arrangement of a unit showing the simplest single osmionic cell. Again we have the cation, and anion, permeable membranes, meaning that positive ions pass through this one, negative ions through that one.

So the simplest possible cell consists of these 4 membranes, 2 cation and 2 anion selective membranes, making up 3 compartments. Originally, all three compartments are filled with the water to be demineralized. This unit then is immersed in a concentrated brine. Therefore, you can visualize the power supply for this process as being supplied by salt mines, brine wells, or even the ponding of saline water and allowing the sun to evaporate and concentrate it.

What occurs is simply this: When immersed in the concentrated brine, the positive ions represented by sodium ions pass through this membrane (C–1) and the chloride ions through this other membrane (A–2). This is electrostatically coupled then with a simultaneous removal of negative ions and positive ions from the inner compartment, so this compartment labeled P, becomes demineralized—potable water.

These other compartments labeled (S) become enriched with salts and more saline than originally.

The brine actually becomes a little less concentrated, so the brine, the material that supplies the power, must be kept up to strength. This is where the salt mines or brine wells enter the picture.

Next slide.

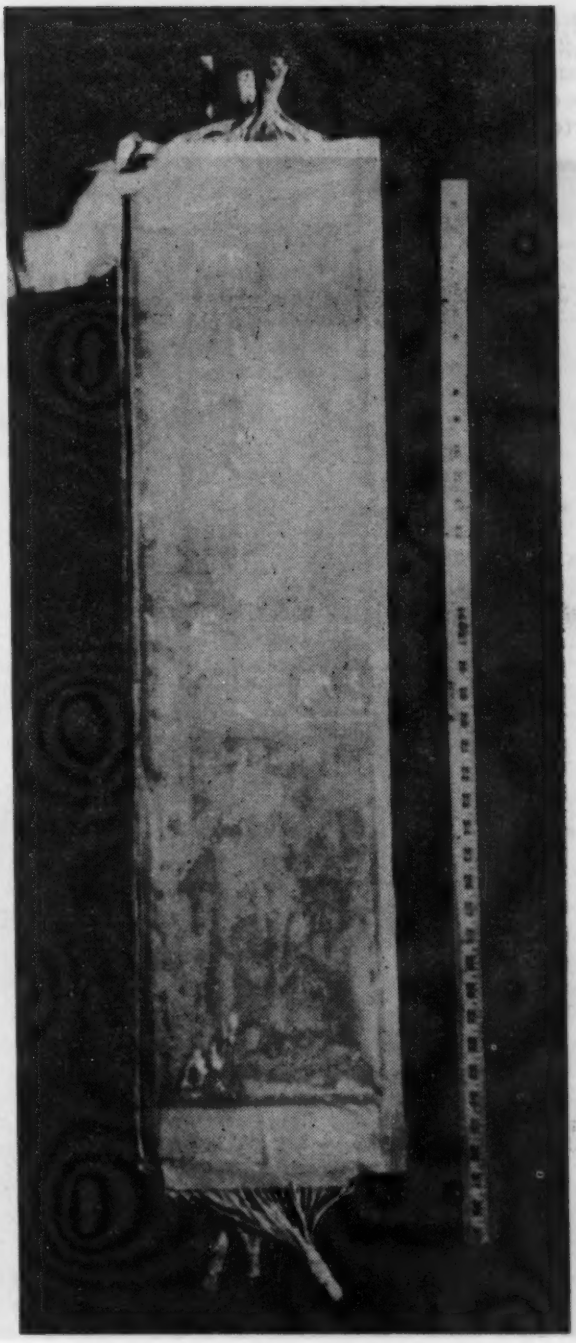
A unit based on the osmionic principle has been fabricated and operated in the laboratory. This process resulted from fundamental research and it is one of the new ideas developed under the program.

Thus the next step was one of development or applied research, building a larger prototype unit to determine whether or not the theory and equations developed hold and to get some idea of the cost we might expect for converted water.

This work is being conducted by the Southern Research Institute at Birmingham, Ala., and we see represented here (Slide 4) a complete membrane pack or unit cell for which we had the schematic diagram just preceding.

This is 8 by 32 inches. It has 3 compartments and the 4 membranes. You see, of course, only the membrane on the top. They are rather translucent, something like cellophane but not as transparent.

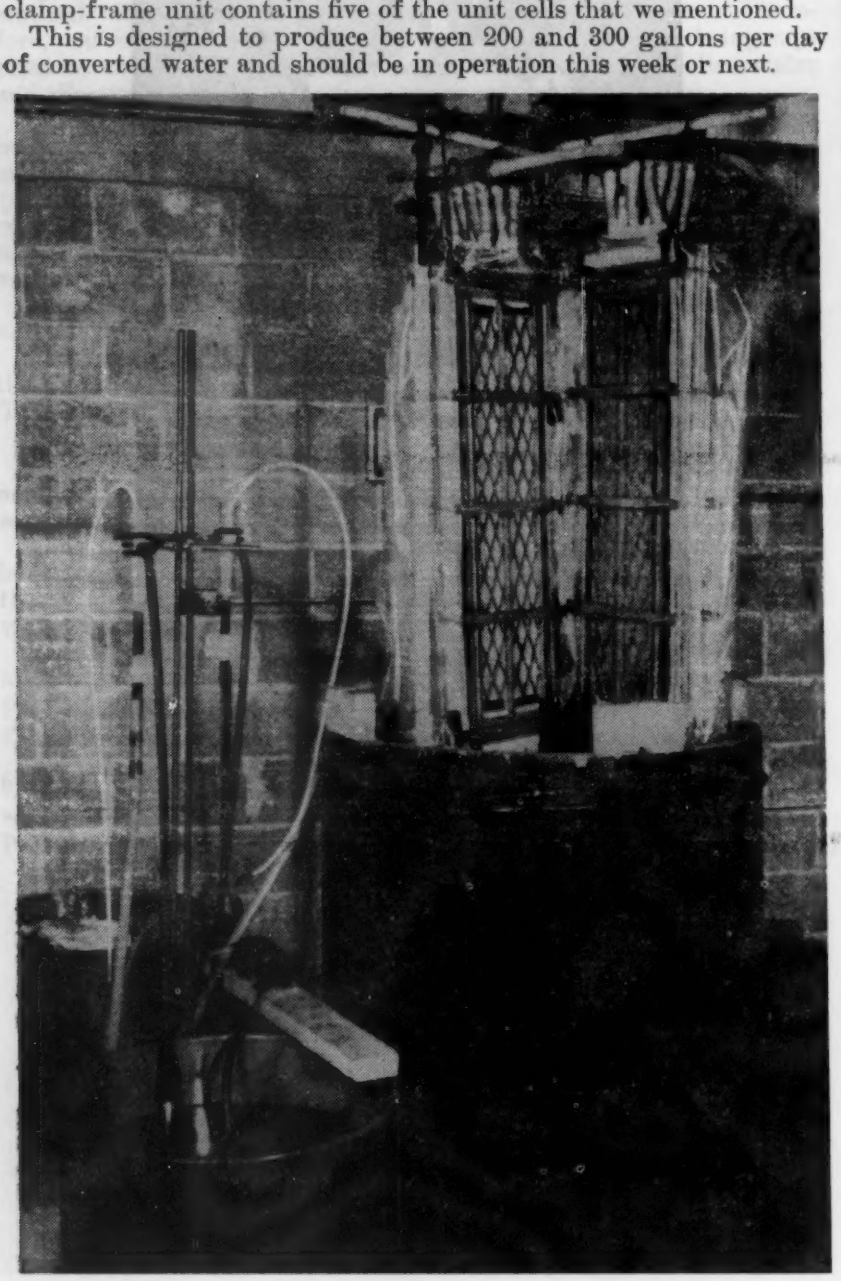
Next slide (slide 4).



SLIDE 4.—Complete membrane pack.

Slide 5 shows a group of 4 clamp-frame units, of which you can only see 2, ready to be dropped into the tank of brine. Here each clamp-frame unit contains five of the unit cells that we mentioned.

This is designed to produce between 200 and 300 gallons per day of converted water and should be in operation this week or next.



SLIDE 5.—View of demineralizer showing clamped-frame units.

From the data obtained from such an experiment, we will be able then to guesstimate at least the cost of converted water we might expect, and come up with some design equations and engineering designs for a much larger unit which will be required in order to obtain better and more reliable cost data.

Next slide (slide 6).

This brings us up to reverse osmosis. We could not find a slide showing the unit that has been fabricated, so we will describe it briefly.

Osmosis, which occurs in nature, in plants, and so forth, refers to the passage of water from a dilute solution through a membrane into the more concentrated solution. This, of course, is the antithesis of the direction of movement we desire. However, if you put pressure on the saline water side, it is possible to force pure water through the membrane into the fresh water side.

In other words, you are reversing the normal passage of water. Hence, the term "reverse osmosis."

A unit based on this principle has been fabricated by one research organization and it produced about 8 gallons per day, which is a rather low rate of production. Some very fundamental work was done on the type of membranes required and their functions.

Based on the results obtained, this group is now in the process of synthesizing better membranes in an attempt to bring the flow rate up to something that would be practicable and acceptable.

The University of Florida is doing this work. They have shown that by the use of a simple membrane like cellulose acetate they can reject 97 percent of the salts in sea water in one pass by squeezing it through this membrane.

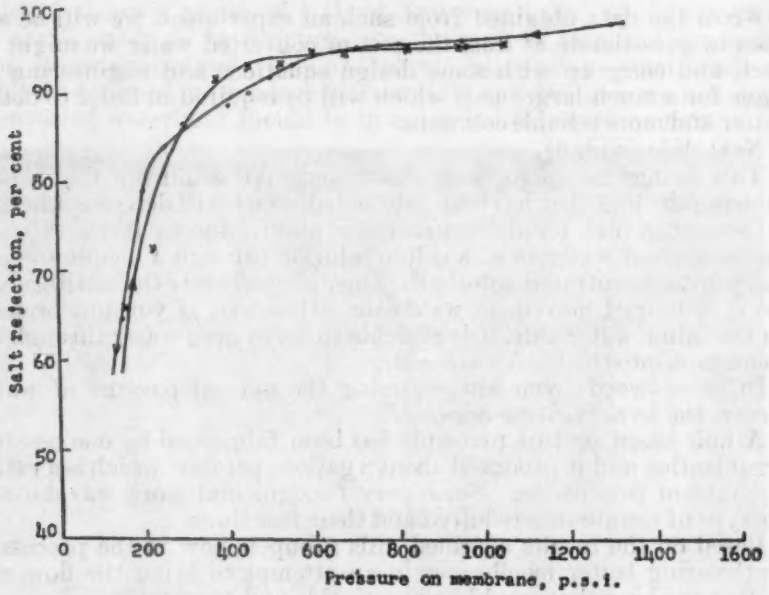
Mr. JONES. What is an acetate, Doctor?

Dr. GILLAM. It is a synthetic polymer or film. It looks a great deal like cellophane, and it is chemically similar to it. The films are available commercially and fairly common.

Mr. JONES. Are they expensive?

Dr. GILLAM. No; relatively inexpensive.

There are two drawbacks to this process that must be whipped before it can be practicable or economically feasible. One is the slow flow rate. The flow rate must be increased, because right now it is measured in microliters per hour.




SLIDE 6.—Effect of pressure on the semipermeability of 40-percent cellulose acetate membranes.

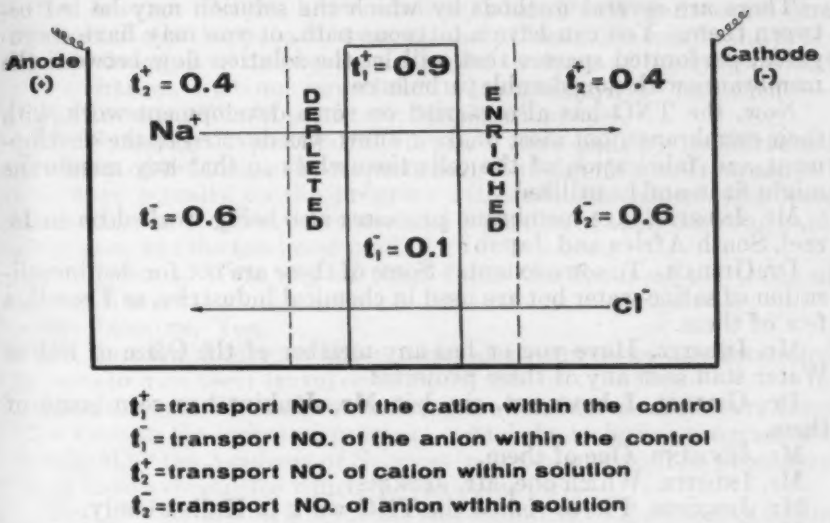
The other drawback is the stability of the membranes. The membranes deteriorate after about 3 months' use. They hydrolyze slowly and eventually the salt rejection is no longer sufficient to give a good product water. This curve in slide 6 merely shows the effect of pressure on the salt rejection of 40 percent cellulose acetate membranes. As the pressure gets higher, the rejection goes up. Some membranes showed a 99 percent salt rejection.

Slide 7 brings us, then, to the final process I mentioned—transport depletion. I will make only brief mention of this diagram and will conclude with this description. It differs from electrodialysis in that in place of the membranes we have layers or zones called controls represented by this dark or shaded area.

These controls might be made up of resins, oxides, or inorganic materials, and could be flakes, granular, or in the form of solutions. They do not have to be membranes. The only criterion is that the transport number of these ions in the control is different than it is in the solution. The transport number may be visualized as being analogous to the speed at which the ions pass through that control or more in the solution under the influence of an electric current. A region depleted of salts will be formed on the anode side of the control and an enriched region will form on the cathode side.

The advantages are these:

With this process, only one type of control is required. You do not need the cation and anion permeable membranes. If the control can be made of inorganic materials the process can be operated under elevated temperatures which might increase the efficiency by some




SLIDE 7.—Transport depletion principle.

20 or 25 percent and, hence, will tend to decrease the cost of converted water.

Well, that concludes my remarks, and if there are any questions we shall attempt to give the answers.

Mr. JONES. Thank you very much, Doctor.

Mr. Knox?

Mr. KNOX. Mr. Chairman, I may ask this question of you. Do you believe that copies of the slides would possibly be of any benefit to the committee if they were reproduced and put in the record?

Mr. JONES. If we get this explanation to go along with them, it would be. We have got part of them here. I noticed one here in your notes.

Mr. KNOX. Well, I just wondered if they would serve any useful purpose by putting them in at certain points through the doctor's explanation.

Mr. JONES. Would you like to have them in?

Mr. KNOX. I just wondered if they would serve any useful purpose. If you think they would, I think maybe we should have them reproduced. I believe you can do that; can you not, Dr. Gillam?

Dr. GILLAM. Yes. We can furnish glossy prints.

Mr. KNOX. I think it would be well.

Mr. JONES. Fine. They will be included accompanying the explanation that the doctor has made.

Mr. Indritz?

Mr. INDRITZ. Dr. Gillam, could you inform the committee concerning the work that is being done on the membrane process in foreign countries?

Dr. GILLAM. We are familiar in a general way with the work being carried on at TNO. Their work has consisted primarily of the development of cell designs and spacers. Now, spacers control the flow path of the liquid through or between the membranes, and a considerable amount of turbulence is necessary.

There are several methods by which the solution may be led between them. You can have a tortuous path, or you may have corrugated, perforated spacers that will let the solution flow between the membranes with considerable turbulence.

Now, the TNO has also carried on some development work with their membranes, but most of their effort was devoted to the development and fabrication of the cells themselves so that any membrane might fit in and be utilized.

Mr. INDRITZ. Are membrane processes also being worked on in Israel, South Africa and Japan?

Dr. GILLAM. To some extent. Some of those are not for demineralization of saline water but are used in chemical industries, as I recall, a few of them.

Mr. INDRITZ. Have you or has any member of the Office of Saline Water staff seen any of these projects?

Dr. GILLAM. I have not, sir, but Mr. Jenkins has seen some of them.

Mr. JENKINS. One of them.

Mr. INDRITZ. Which one, Mr. Jenkins?

Mr. JENKINS. I have visited the TNO work in Holland only.

Mr. INDRITZ. Do you think that it would have been helpful to see all of the different processes? Would it be possible, for example, to get one of their machines brought to the United States for you to examine?

Dr. GILLAM. We have considered that and have negotiations underway at the present time for the purchase of one of their units, a test unit, to bring over here and put in the laboratory at Denver to compare with other units.

Mr. INDRITZ. Is testing now going on at Denver on the American membranes?

Dr. GILLAM. Yes.

Mr. INDRITZ. Would you say that the foreign countries are putting a larger proportion of their effort into membrane process research than the United States?

Dr. GILLAM. I believe that to be true in the case of TNO. I do not know the total amount of money they have put into the development, but I would guess that, along with the Union of South Africa it is considerably more than we have expended in this country.

Mr. INDRITZ. Have you any suggestions as to how the United States, including the Office of Saline Water of course, can do more to speed up the research on membrane processes?

Dr. GILLAM. Well, we have several things which we think should be done. They have been initiated. They are going along slowly. They are going along as well as possible with, I guess, the limited manpower and funds available.

Mr. INDRITZ. Have you made any effort to stimulate production of cheaper membranes by companies in the United States?

Dr. GILLAM. Yes. We have had very good liaison with several companies. They have visited the office. We have talked with them. And they have carried on a great deal of research and development on their own with their own funds.

One of those companies I mentioned now is offering improved membranes at greatly reduced prices in quantity—membranes in quantity.

Mr. INDRITZ. Do you know whether, when Dr. Wegelin came here from the Netherlands to the symposium to discuss the membrane process, his travel costs had been paid by the sponsors of the symposium?

Dr. GILLAM. I am not sure of that. I would have to check with——

Mr. INDRITZ. Would you know, Mr. Jenkins?

Mr. JENKINS. A portion of his costs were paid by the National Academy of Sciences. There were 6 or 7 of the visitors from abroad who were actually on the program with technical papers who were invited by the Academy to come, and a portion of their cost was paid. In no case was the total cost paid.

Mr. INDRITZ. Were any of these funds the funds of the Office of Saline Water?

Mr. JENKINS. Yes.

Mr. INDRITZ. Did your Office reject any requests by any interested persons to have their travel costs paid?

Mr. JENKINS. The only ones that were considered at all were those who were on the technical program. And the technical program was arranged by the Academy of Sciences in accordance with its procedure. They have a committee which they appoint for——

Mr. INDRITZ. Is that outside the responsibility of the Office of Saline Water?

Mr. JENKINS. Yes.

Mr. INDRITZ. It was outside your responsibility?

Mr. JENKINS. That committee was selected by the Academy of Sciences for determining what papers were to be in the symposium. I served on it and we advised with them, because we wanted to be sure that all of our contractors were represented. And they asked us for suggestions also.

Mr. JONES. What is the purpose of the inquiry, Mr. Indritz? Is it to show that there was a discrimination on the part of Mr. Jenkins and his people, or is it for the purpose of showing that——

Mr. INDRITZ. On the question of travel costs, sir?

Mr. JONES. Yes, sir.

Mr. INDRITZ. There had been a complaint by a person who said he invented a new desalinization process and that his request for travel costs to the symposium had been denied. But Mr. Jenkins has now responded that that was outside the function of the Office of Saline Water.

I understand that the State of Israel has had an electrodialysis program subsidized by the United States under the informational mediums guaranty program and that that project was submitted to your office for your review or recommendation to the State Department. Have you made your recommendation to the State Department?

Mr. JENKINS. Yes, sir.

Mr. INDRITZ. Did you include in that recommendation any conditions to assure that the information which would be developed by such research, and which is financed by the United States, would be available to the United States?

Mr. JENKINS. Mr. Indritz, I will have to answer that question.

Mr. INDRITZ. Please do.

Mr. JENKINS. In our arrangement with the Department of State that is a general provision that the information will be supplied to this country.

Mr. INDRITZ. Do you also have a provision permitting representatives of the United States to inspect these Israeli processes which are thus financed by the United States?

Mr. JENKINS. No, we do not. And I am not really sure that that is United States money. That is money——

Mr. INDRITZ. It is money appropriated by Congress, though.

Mr. JONES. If there is liaison between the foreign countries in accordance with the terms of the act and there is general diligence on the part of the agents to acquire the information that is being obtained through their research and development programs, I think that is generally our business to inquire into.

Mr. INDRITZ. I have no further questions at this time.

Mr. JONES. Now, I am sorry that we were not able to complete hearing all the witnesses today. That leaves us with Mr. Strobel and Mr. Cywin and Dr. Leopold.

Dr. Leopold, it was our intention to take you at the conclusion of the other witnesses with the Department of Interior.

So I wonder if you could be available tomorrow at 2 o'clock for another run? Is that satisfactory with you, Mr. Strobel?

Mr. STROBEL. Yes.

Mr. JONES. And to you, Mr. Cywin?

Mr. CYWIN. Yes, sir.

Mr. JONES. Now, that leaves us with you, Dr. Leopold.

Do you have any other witnesses, Mr. Jenkins, that you want to tender to the subcommittee?

Mr. JENKINS. No, sir.

Mr. JONES. Any further questions, Mr. Knox?

Mr. KNOX. No, I believe I have no questions, Mr. Chairman.

Mr. JONES. The subcommittee will stand adjourned until 2 o'clock tomorrow afternoon.

(Whereupon, at 4:35 p. m., the subcommittee adjourned, to reconvene at 2 p. m., Wednesday, April 16, 1958.)

# SALINE WATER PROGRAM

## (Research and Development)

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WEDNESDAY, APRIL 16, 1958

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON PUBLIC WORKS AND RESOURCES
OF THE COMMITTEE ON GOVERNMENT OPERATIONS,
*Washington, D. C.*

The subcommittee met, pursuant to adjournment, in room 1501, New House Office Building, at 2 p. m., Hon. Robert E. Jones (chairman of the subcommittee) presiding.

Present: Mr. Jones and Mrs. Granahan.

Also present: Arthur Perlman, staff administrator; Phineas Indritz, subcommittee counsel; and Miles Q. Romney, professional staff member.

Mr. JONES. The subcommittee will come to order.

We are, of course, delighted to have, not a newcomer but a newcomer to our committee. This is the first opportunity she has had to attend the sessions of the subcommittee, and I know that I can speak for the absent members, Mrs. Granahan, in wishing you welcome. I know your services on this committee will be quite valuable and worth while and your capabilities will contribute immeasurably to the success of the work of this committee.

Mrs. GRANAHAN. Thank you, Mr. Chairman. I am very happy to be on the committee, but I think I will have to buy a new hat with that flattery you are giving me.

Mr. JONES. To bring you up to date on our hearings of yesterday, we concluded with the Assistant Secretary of the Interior and with Mr. Jenkins, the Director of the Office of Saline Water. We had Dr. Gillam on yesterday afternoon, and we were down to hearing Mr. Strobel and also Mr. Cywin. It is my understanding that Dr. Schroeder is here. He is going to have to make a departure in order to catch a 4 o'clock train, and so I am going to ask the indulgence of those witnesses that were scheduled earlier in order that we can hear from Dr. Schroeder and have the benefit of his testimony. Without objection, I am going to call on Dr. Schroeder at this time.

Dr. Schroeder, we are glad to have you today. We understand that you have done considerable work in the field of saline water at the University of Maryland, and I am quite sure that your testimony will be of value to the committee.



26941—58——7

## STATEMENT OF W. C. SCHROEDER, PROFESSOR OF CHEMICAL ENGINEERING, UNIVERSITY OF MARYLAND

Dr. SCHROEDER. Mr. Chairman and members of the committee, most of my work has been done actually in connection with the evaluation and study of perhaps the overall aspects of the processes and the programs as a whole, and I have tried to keep my testimony pretty much in that vein.

Mr. Chairman, if it is agreeable to you I will not read this. I think you have copies of it. I would like to brief it orally, if I may.

Mr. JONES. That will certainly be in order, Dr. Schroeder, and without objection your statement will be included in the record at this point.

(The prepared statement of Dr. Schroeder follows:)

STATEMENT OF W. C. SCHROEDER, PROFESSOR OF CHEMICAL ENGINEERING, UNIVERSITY OF MARYLAND

The production of fresh water from sea water or brines has been a fairly large-scale industrial operation for decades. A good many methods are technicaly feasible for separating salt and other undesirable impurities from water. It is evident that the saline water program as conceived in the original legislation by the Congress was concerned with the economic cost of the separation process. This study of the economic factors could and has led in two directions: First, the development of new methods which offer lower cost fresh water production; or, second, the improvement of existing methods to achieve the same purpose.

### DIFFICULTIES OF ECONOMIC RESEARCH

Economic research of this type carries with it a number of peculiar and difficult problems. The cost of the final fresh water is made of these three major items: (1) The cost of the heat or energy used; (2) the direct costs of operation; (3) the writeoff of the capital investment in the plant.

It is possible to eliminate one of these items entirely and yet have high-cost water. An example of this is solar evaporation. In this case there is no cost for heat or energy, but the energy is so diffuse and the plant must be spread over such a large area that the capital as well as the operating costs may nullify this advantage.

Numerous examples of this type may be cited. Therefore, in order to arrive at sound conclusions, a careful accounting must be made of all the costs that go into the final product. This often involves a large amount of detailed calculation.

An important factor in these calculations is optimism versus engineering judgment. I do not mean to say that these are, necessarily, incompatible, but far too often the proponent of a process allows optimism to hold sway to such an extent that he gives his process every conceivable (and some inconceivable) break. This often leads to widely divergent figures from the process developer as contrasted with a strictly engineering analysis.

To avoid overoptimism, many industrial organizations take the cost estimating out of the hands of the developer and put it in the hands of a special group which will not be emotionally concerned with the process itself.

The saline-water program has taken a first step in this direction in the establishment of a standardized procedure for estimating costs of saline-water conversion. This procedure will undoubtedly be improved as time goes on, but it is also important that the Office of Saline Water review the estimates prepared to make them as comparable as possible.

The state of development of the processes is of great importance in establishing the costs. For example, under a given set of conditions the cost of water from a distillation plant could be estimated with considerable accuracy, since most of the cost factors in this process are well known and large-scale equipment has been built and operated all over the world. On the other hand, a process just out of the laboratory stages of development is subject to much

greater uncertainty and it may, in fact, be impossible to arrive at any estimate other than an educated guess.

A final, and, perhaps, one of the most baffling, problems is that estimates of the cost of the final product will differ even after a plant is in operation and running. Controversies on the cost of electric power, on the cost of a ton of steel or a barrel of oil, are illustrative of the difficulty of arriving at figures which are generally acceptable. Fundamental questions are involved here concerning items such as the rate of amortization of the plant investment, taxes, insurance, and profits. In the saline-water program it would appear that the best procedure would be to establish a calculation method, as has been done, and to follow this in all cases. This, at least, has the advantage of making the estimates comparable.

Difficulties and disagreements in cost calculations lead to further problems. Measurement of progress is uncertain, and progress that is claimed is often susceptible to attack. Often, and, in fact, in most cases, in this type of research, progress is by a steady evolution of numerous ideas, each of which contributes only a small improvement, but which, in total, finally add up to major cost reductions. Such work is not dramatic, and without close scrutiny it may even be difficult to see the progress.

### HOW TO MAKE FRESH WATER

The traditional way to make fresh water from sea water is by distillation. This means that about 96.5 pounds of water must be evaporated from 100 pounds of sea water to leave behind 3.5 pounds of salts. This is much like moving aside the whole haystack to find the needle. It should be much less work if we could simply remove the salt without bothering all the water.

Both chemical and electrical methods are known for doing exactly this. They have been intensively studied, in part, in connection with the present saline-water program. They appear to have economic advantage for brackish water containing perhaps one-tenth the salt in sea water, but distillation processes still seem best for sea water.

It appears to me that the saline water program has gone to great lengths to bring out any new approach that would offer a striking breakthrough on the processing of sea water. During the first 3 or 4 years of the program (and even now), all ideas were solicited. Some turned out to be pretty fantastic. Nothing new which was of striking promise came up. Additional interest and possibilities were generated in some old ideas, such as freezing and solvent extraction, and some of these processes are now under investigation.

At the present time, distillation processes are the most suitable for making fresh water from sea water, and the Office of Saline Water has, accordingly, devoted a major effort to improving these processes.

A relatively new distillation process, using rotating surfaces, has achieved high rates of heat transfer and good yields of fresh water while operating at low temperature levels. This process is now being investigated thoroughly. It has disadvantages, however, in that the capital cost of the equipment may be relatively high and a considerable portion of the energy used in the process has to be supplied as electrical energy. This is higher cost energy than heat energy.

Other improvements in the distillation processes have been achieved by the use of a large number of multiple effects and by the use of simple designs with low construction costs. These changes help to reduce energy requirements for the plants as well as the initial capital costs.

The formation of scale still remains as one of the troublesome problems in distillation processes. Sea water is especially difficult, since it contains high concentrations of salts that readily form scale. To some extent, the problem can be avoided by operating at low temperatures, but this tends to limit the efficiency and to reduce the throughput from a given unit. Chemical processes are available which will alleviate scale formation, but these all add to the cost of the fresh water.

I believe that a great deal can be done to eliminate scale formation. The problem has not been studied sufficiently, especially as it concerns the evaporation of sea water. It is my understanding that the Office of Saline Water has started both laboratory and pilot-plant studies on scale prevention. This work should be adequately financed and should be pushed vigorously.

### HOW MUCH IS FRESH WATER WORTH AND HOW MUCH DOES IT COST?

The value of fresh water runs the gamut from being worth as much as a precious metal to being a nuisance and a destructive force. On the desert, a small amount may mean the difference between life and death. During a flood, water can be a serious liability.

Between these extremes, fresh water can still fall in a broad range of values. On board ship, it may be prepared by evaporating sea water with oil heat for cooking, drinking, and washing purposes. In such a case, its value is in the range of $3 to $4 per 1,000 gallons. Industrial uses of water also cover a wide range. For steam to be used in process operations, it may not be too much to pay $1 or $2 per 1,000 gallons for the water fed to the boilers. For municipal use, water at 20 cents to $1 per 1,000 gallons is normal. For agricultural use, probably about 15 cents per 1,000 gallons (about $50 per acre-foot) is the maximum that even the better farms could stand.

All of the processes which have been conceived up to the present time for producing fresh water from sea water (or even brackish water) are relatively expensive. At their present state of development, they can and are being used to produce water for $2 to $3 per 1,000 gallons. Where fuel is available at little or no cost, for example, as waste gas from an oilfield or refinery, the cost can be reduced to the range of $1 to $2 per 1,000 gallons.

For very large plants using fuel in the normal range of present United States prices, it seems to me that about $1 per 1,000 gallons is a realistic figure. I have seen estimates that show less than half this figure. In my opinion, these assume an unwarranted number of favorable factors and conditions. It is the sad experience of most engineers that actual costs have a chronic tendency to run up rather than down from the estimates. Even water at $1 per 1,000 gallons would demand favorable conditions and the utmost in keeping down the capital cost of the plant.

If my analysis of this problem is correct, fresh water from sea water is now possible for some industrial uses. It may also be coming into the range of economic possibilities for certain municipal applications. It is a long way from being economically feasible for agricultural applications.

It must also be realized that present calculations for the cost of fresh water are based on essentially continuous operation of the plant and use of the product water. This is often possible for industrial or municipal applications. In the case of agricultural use, the demand may be concentrated in a few months of the year. For this intermittent operation, the cost of the water would be much higher and, in fact, this type of operation is not really economically feasible. This means that large storage areas would have to be built, which would add considerably to the cost of the product water.

Before large plants are built for producing fresh water from sea or brackish water, consideration will be given to other means which might meet the requirements. I have not attempted a survey of the United States, but it is my belief that stream diversion, water storage, and the building of aqueducts will, at the present time, meet nearly all requirements at lower capital costs, and lower costs for the product water, than the processes under consideration here.

This may sound pessimistic, but that is not the intention. Rather, it should be taken to indicate that we may still have some years for development work before we need to commit large sums to the building of commercial plants.

It is apparent, however, that there is a need for a thorough survey of future water requirements in various areas of the United States. This should be coupled with an analysis of the water supply available to these areas, including normal rainfall, underground water, streams, and possibly water storage. From this program conclusions should be possible concerning times and places where fresh-water plants will be needed, and the saline water program can be guided to meet these goals.

### FUTURE PROGRAM

The saline water program has thoroughly examined a wide variety of ideas for producing fresh water from sea or brackish water. From this work about 5 or 6 processes have been selected for thorough investigation. The most promising of these methods are now moving into pilot-plant investigations. This work will require substantially greater annual appropriations if it is to be carried on most effectively.

At the present time, distillation processes seem to be the most satisfactory for the conversion of sea water to fresh water. Scale formation is a troublemaker

and handicap in all of these processes. A thorough investigation directed toward preventing this trouble should be pressed as rapidly as possible.

Problems involved in the production of fresh water are largely cost problems. This is a field in which the exercise of engineering and economic judgment is unavoidable. It is therefore essential that the Office of Saline Water should work steadily toward the development of a sound cost estimating procedure, and that all estimates should be put on as nearly comparable basis as possible. A good start has been made but more remains to be done. Funds and personnel will be needed for this work.

A final important question is, When will the United States need fresh-water plants? Some people may answer, "Now," but this is only the case if the fresh water cannot be secured more cheaply by other means. To answer this question I believe that a study should be made of all sources of available water for arid sections. From this it should be possible to arrive at some idea as to when the fresh-water plants can take their place in the economic picture. Up to that time, it would be most logical to continue the present program on a development and pilot-plant scale.

Mr. JONES. You may proceed in your own way.

Dr. SCHROEDER. One of the things about this program that has always deserved careful consideration is that when the program was started, and in fact long before that, the engineering world, and the lay world as far as that is concerned, has always known how to make drinking water or fresh water from sea water. So in essence when this program was started by the Congress you were not necessarily asking somebody to invent something that was not in existence. You were in effect asking them perhaps to improve known processes or, if they were lucky enough, perhaps to come up with a new concept or a new way of making fresh water from sea water. Inherent in such law is the idea that this is an economic problem. Since we know that if you disregard economics we can make fresh water, then this law automatically puts us into the realm of calculating and developing the cheapest method for doing this.

Now, the saline water program might have started out and said: "Well, we know that all the methods we have available are fairly expensive compared to taking water out of a river or digging a well in the ground or bringing water in by aqueduct from a stream some miles away. Nevertheless, we might be lucky enough to hit on a process which is much better than anything we have had heretofore." I think that perhaps not only in the mind of the people in Congress but in the mind of the technical people as well this possibility loomed large. So when the program was started there was a strong seeking of ideas. I think that was true not only in the Government but outside of the Government and in industry as well. People were seeking new ideas, new concepts that would allow the economical evaporation of sea water.

One of the first things we thought of was, "Well, since sea water contains 3½ percent salt, by evaporation processes we are taking away the 96½ pounds of water to leave the 3½ pounds of salt." A rough analogy might be to say we were moving the haystack to find a few needles. A lot of people conceived the idea that maybe we could turn this thing around and take the salt out and leave the water alone, and such processes were developed. But it turns out that even those processes, when you got through with them, really were not so much more economical than the evaporation process. So we were stymied a little bit in that respect.

After some years of searching, I think it is fair to say that, as far as the technical viewpoint is concerned, there have been no really new breakthroughs with respect to the preparation of fresh water from sea water. Our progress has been largely through the modification of ideas that were known at the time that this program came into existence. Now, that may seem to you to be perhaps a little bit disappointing; but, as a matter of fact, since we had faced this problem of evaporating water for centuries already, I suspect a lot of very intelligent people have done some heavy thinking on it in those centuries.

Mr. JONES. Doctor, this subject is entirely new to me and I am trying to get briefed on it, but it seems to me that there has been very little progress made since Thomas Jefferson was Secretary of State, as far as distillation is concerned.

Dr. SCHROEDER. I would not go quite so far as to say that, but in a sense I agree with you. May I go on?

Mr. JONES. Go ahead.

Dr. SCHROEDER. So really after, I think, a pretty thorough examination of a great number of ideas, some sensible and some pretty fantastic, I think that the Office of Saline Water was forced back to the conclusion that they had to do the best they could to improve processes that were really known processes. Now, immediately when you reach that conclusion and you say that you are going to improve known processes you come up against the question, "How do you measure improvement in any research or development program?" Well, you have already stated your answer really. The only way you can measure your improvement is to determine if the water costs you less from the new process or new ideas that have been suggested. And how do you determine whether the process costs you less when you have no plant in existence? You do it by estimating the cost of the plant and the cost of operating that plant. And immediately when you say that then you bring in a lot of engineers and accountants and statisticians and lawyers and other people who like to argue and disagree about things. So it becomes difficult then to really measure whether you have made progress or whether you have not made progress, and even if you assert you have made progress there are always other people who will assert that you have not made progress. Now, to get to the question of what is the cost of fresh water from sea water or brackish water we have three major items of cost that we must consider. We have the heat or energy that we must supply to the process. We have the costs of the operation, and then it costs us something to build the plant, so every gallon of water that goes out carries part of the investment of that plant with it. It must carry part of that investment of the plant with it.

Now, you must consider every item of those three. It is often possible to find a process for which you could get the heat or energy at relatively little or no cost. Solar evaporation is one of these processes. But the trouble is that this is diffuse energy. It is not concentrated energy, so you literally have to cover acres of land to make a few thousand gallons of water a day, and the result is that your capital cost in your plant may go so high that it writes off the advantage of no energy cost, let us say. So in any accounting of the cost of operation you must make sure that every item is included in this thing.

Another thing that comes in in trying to measure the progress you are making by measuring costs is this question of the attitude of the man who is doing the cost work. A lot of inventors, people who are promoting processes, tend to be overly optimistic about their work. I think they try to be fairminded. I think they try to be honest, but they become optimistic. Their pencils become sharper and sharper as they go along, and they cut costs here, there, and everywhere until finally they come out with a figure which suits them, at least partially. Many large organizations, private organizations, in the United States have recognized this difficulty for years, and when it comes to making cost estimates they take this problem away from the developer and inventor. They put it in a separate group who will exercise analytical judgment on this thing without being emotionally involved with the process and whether it is successful or unsuccessful. In that way they feel that they get a much fairer evaluation of their possibilities.

The saline water program early recognized this difficulty, and they drew up a more or less standardized procedure for estimating costs. I think in general it has been agreed that this is reasonably helpful. At least I want to feel so. I did quite a lot of work drawing it together, so I want to feel it was helpful. But in any case like this it is impossible to standardize the thinking of diverse groups and diverse organizations, so that I think it is going to be one of the problems of the saline water group to go over these estimates as they are submitted to them and to bring them down to a common basis or standard. As I understand it, work in that direction is now going on.

So, however you may look at it, we have a pretty tough problem here. It is an economic problem. We have not developed any completely new breakthroughs with respect to the production of fresh water from sea water. Improvements have been made in distillation processes to some extent. We have this Badger-Hickman development, which offers heat transfer rates perhaps 3 or 4 times the normal rates encountered in evaporation. On the other hand, this equipment turns out to be considerably more costly than most evaporators, which offsets that advantage. It has another disadvantage in that the energy supplied must be supplied as electrical energy rather than heat energy.

In addition to that step forward in evaporation, there has been the idea of using a large number of multiple effect evaporator systems, as many as 15 or more, so that instead of evaporating 2 or 3 pounds of water per pound of steam we can come up with 12 or 15 pounds of water per pound of steam. This does not come to us free. We have to put more capital into the plant to get this large amount of evaporation. We cut our energy costs but we increase our capital costs.

So progress has been made to some extent I think in distillation. Progress has been made on ion separation, particularly as applied to more dilute water than sea water, and there are other schemes like solvent extraction and freezing which are now under investigation and which perhaps it is too early to talk about yet with respect to costs.

If I may leave that subject for a moment, I would like to talk a little bit about the question of how much fresh water is worth and how much it costs, not only from processes such as we are considering here but other means of securing fresh water as well.

Well, I suppose in a sense fresh water is worth to you what you are willing to pay for it. If I remember correctly, during the recent dry period down there in Texas water was hauled into some of those cities, and they were paying 25 and 30 cents a gallon for it. I am recalling these figures from memory, but people were willing to pay a considerable price for it. On board ship, for example, we have long evaporated water with steam from the boilers or perhaps with direct oil heat, and I am quite certain that that water would cost you in the range of $3 to $4 per thousand gallons. We are willing to pay that to use that water for cooking, drinking, and cleansing purposes on ship. Industrial waters cover a wide range. If you want process steam for a chemical plant, the actual cost of that steam in your final product might be negligible, and it would not be unusual to think of paying perhaps a dollar a thousand gallons for industrial water for a boiler. On municipal water, I think in this area we pay around 20 or 30 cents per thousand gallons. In some areas it is considerably higher than that, but probably in the range of somewhat under a dollar a thousand gallons is reasonable for municipal water. With respect to agricultural water, I suppose even a good farm could not afford to pay more than 10 or 15 cents a thousand gallons, since this comes into a range of about $30 or $50 per acre foot. If you need a foot of water for a season, you could not afford to pay much more than $30 an acre, let us say.

Now, all the processes that have been conceived and talked about to date for production of fresh water from brackish water or from sea water are relatively expensive. I have gone over a lot of calculations. I have made a lot of calculations myself. I have seen calculations indicating that you can take sea water and make fresh water for 40 cents a thousand gallons. I have made some calculations myself in which I concluded that there was a bare possibility you could make fresh water from sea water for 70 cents a thousand gallons. If you pushed me hard, I would hate to say that you could make fresh water at the present time from sea water for anything less than a dollar a thousand gallons, and then you would work a big plant and you would keep your costs to the absolute minimum to get that figure.

I realize I am probably going to disagree with some of the people in this room, but that is more or less my own feeling on this thing after having looked over all these figures.

It is perhaps fair to say that most engineers find that when they actually get into operation the costs tend to creep up from their estimates. Perhaps if you had the experience of building a house you may have gone through that same sort of an operation. I mean the house started out at $30,000 and ended up at $40,000, and a house is a comparatively simple thing compared to what we are trying to do in a program like this, forecasting costs on the basis of relatively small amounts of experimental work.

If you put those two groups of ideas together, it would indicate to you that our present state of knowledge, engineering and economic, shows we perhaps could furnish water for industrial use by evaporation or other purification processes. We perhaps could furnish it for some munipical use. But it looks to me as if we are quite a long way from furnishing water for agricultural use.

I think at the same time in any of these processes that are developed the strong tendency is going to bring them in under the biggest umbrella, the biggest cost umbrella. So they are therefore going to look for outlets where water is most expensive, and this is inevitably true in any development of this type.

Now, this raises a question as to when really we need these plants for the evaporation of sea water or brackish water. I suppose that in all fairness many people would say we need these plants right now. There are certainly areas of the Southwest and there are areas in California and perhaps other places where the population could grow considerably and industry could grow considerably if we had more fresh water. But it is only fair, when you make that statement, that you look around to see whether there is any other way to bring water to these areas. It may be necessary to build long aqueducts or long pipelines. It may be necessary to build water storage. It may be necessary to seek underground water. But I am inclined to believe that in many areas of the United States it certainly would be possible to follow these other sources for the next few years and bring water to those areas at a lower cost than we could bring it from the processes we are talking about here.

I do not mean that statement to sound discouraging. Maybe it does, but I do not mean it to sound discouraging.

How long a period of development do we have before these processes have to go into operation? Well, this is purely a question of when these processes become competitive with other means of securing water, and while I have no survey of the United States as a whole or of given areas of the United States, still I am inclined to believe that there are some years ahead of us in which we can bring fresh water into most of these areas at lower costs by other means. If that is the case, I would be inclined to believe that we have still got a number of years of development work on this program, development work to include pilot-plant experimentation and perhaps the building of some larger scale plants, perhaps in the neighborhood of 25,000 or 50,000 gallons a day. It seems to me that that would be the most economical way to go forward.

Now, to summarize what I have said here, as I see the picture today the best processes we have for making fresh water from sea water under this program are the distillation processes. Even with all their faults and even with difficulties in making progress, they still seem to be the best for this purpose. They have one drawback which I think is serious, and that is this question of scale formation, which has been a difficult problem in all the evaporation processes. I believe that that deserves very thorough and careful attention, and I would recommend that that work be pushed as hard as possible.

The second thing that I think ought to be done is that we have got to realize that all of our measurements are being made by cost estimating. I think the Office of Saline Water would be thoroughly justified in making every effort to bring their cost evaluations to as nearly a comparable basis as possible and to make them as factual as possible. I think they are striving in that direction and that work should go forward.

I think as a matter of deciding how soon you want these plants and how soon you need them there ought to be some survey made

of the more arid sections which are really in need of water, to determine what water sources are available to them. I mean not these evaporation processes but by aqueducts and storage, and so forth, and to determine if possible what it is going to cost to bring water into those areas from these plans that are now well known and perhaps well understood. On the basis of that sort of information, I think we could decide on perhaps with what speed and in exactly what direction this program had to move forward. I think that covers it.

Mr. JONES. Thank you very much, Doctor. Mrs. Granahan?

Mrs. GRANAHAN. No questions.

Mr. JONES. Doctor, you have some allowances of time for research, and I recall the estimates of the Hoover Commission's report to the Congress on water resources and power, which estimated that by 1975 we would need about eleven additional Colorado rivers, that we were increasing the water consumption at that rate. If that schedule is kept, would you reduce the number of years that we have to carry on that research? You say that there are other more economical means to go about procuring fresh water within the foreseeable future.

Dr. SCHROEDER. I think in a case like this my own feeling would be that you almost have to pick a city or an area.

Mr. JONES. Let us take one like San Francisco. My recollection is that they transport water 176 miles.

Dr. SCHROEDER. That is right.

Mr. JONES. And there is a limited amount of water available to San Francisco and northern California. They are talking about a diversion from the Willamette River up in Oregon to supply the water requirements of northern California. Now, what would your arithmetic be in that sort of situation?

Dr. SCHROEDER. Without having done it, I would be inclined to believe that you could reach a good many hundreds of miles for a stream to bring water to Los Angeles as compared to installing evaporation plants or separation plants using sea water in the Los Angeles area. I make that as a general observation.

Mr. JONES. Let me ask another question. As I understand it from the testimony of witnesses yesterday, the removal of dissolved salts from brackish water is much cheaper and more satisfactory than from sea water. Now, would San Francisco go up first to the Sacramento River, or seek brackish water, and then move into sea water later on, or how would you proceed to satisfy that need?

Dr. SCHROEDER. I would not reach for brackish water. I would reach for fresh water that could be used directly without any evaporation or membrane process.

Mr. JONES. But suppose you do not have anything but brackish water. You either have brackish water or salt water. If you had fresh water you would not need the distillation.

Dr. SCHROEDER. My own feeling on that would be that you could reach perhaps all the way to the western slope of the Rockies if necessary, rather than to go through a distillation process.

Mr. JONES. At the present cost?

Dr. SCHROEDER. At the present cost, yes. But I say this without having figures in front of me. It is just my feeling on the matter.

Mr. JONES. Because we are—I would not say that far behind in research, but we are not that far advanced?

Dr. SCHROEDER. That is right. When you look at the costs, most of these capital costs for these plants come to a dollar or dollar and a half per gallon per day. So for a thousand gallons, let us say, at $1,200 for a thousand gallons, 100,000 gallons would cost you $1,200,000, and a million gallons would cost you about $12 million in a plant investment alone, besides your fuel and other operating costs.

Another thing you have to consider in this California areas is that it is a very poor area for fuel. There is no cheap coal out there at all. If you are going to get coal, you are going to get it from New Mexico or Utah and ship it into California, and your costs are probably going to run in the neighborhood of $12 or $14 or $15 a ton. On residual oil out there, the best you can do now is probably around 40 cents a million British thermal units. Gas is in short supply in California already. It is worth 30 to 32 cents a million British thermal units, and chances are if you are going to put up a big plant your fuel costs are high. So in addition to a big capital investment you are going to have a high fuel cost.

Mr. JONES. Doctor, have you served on the committee that was appointed to aid the Office of Saline Water?

Dr. SCHROEDER. I was on a committee originally that was a Government committee, but I have not served on this advisory committee.

Mr. JONES. I thought you had served on that.

Mr. INDRITZ. Dr. Schroeder, you have mentioned among the ideas which are still being researched, the problems of research on freezing, solvent extraction, and the scale problem. Do you not think there are still many other basic problems on fundamental research that still must be gone into both deeply and quickly, such as the increases in heat transfer rates, heat storage, crystal structure, the nature of ions, hydrogenation effects, and so forth?

Dr. SCHROEDER. I think there is a great deal of work that remains to be done on this question of increased rates of heat transfer. For instance, the Badger-Hickman still has achieved rates as high or close to 4,000 British thermal units per square foot. Normally we get in the order of 800 or so. But when that unit was blown up to a bigger size unit actually those rates seemed to fall off, and I have never been satisfied that that falloff ought to occur. I feel that we do not understand the situation and that there is a great deal to be learned there.

Then there are a lot of people who have done research on what we call dropwise condensation rather than film condensation in these various types of evaporating units, and they have achieved heat transfer rates that are much higher than anything we normally get in an evaporator. While this is on the steam side of the evaporator and somewhat less significant than if it were on the water side, yet I think we could learn a great deal if we studied these heat transfer rates much more carefully.

With respect to this question of crystal formation, I think that goes right back to this question of preventing scale. We know very little really about what happens when you evaporate water and why certain salts will stick to the metal surfaces, like calcium sulfate or calcium silicate and certain magnesium salts, whereas other salts come down and do not cause any trouble at all. I believe that a great deal could be learned in that direction, and it is my understanding that the

Office now has a program at the University of Michigan studying scale formation. I am heartily in favor of pursuing that subject as vigorously as possible, with more money if necessary.

Mr. INDRITZ. In connection with the statement you made a moment ago that many years may pass before we must engage in large-scale distillation or other desalinization in order to supply fresh-water needs, isn't there frequently a very long lag between the completion of basic research and its application into a commercial basis?

Dr. SCHROEDER. Yes, it can be very long.

Mr. INDRITZ. So that sometimes the achievements of today had to be started 10 or 15 years ago?

Dr. SCHROEDER. That is right.

Mr. INDRITZ. And would that not indicate that every possible effort ought to be made to expedite the basic research as well as the applied development of the processes that we already know?

Dr. SCHROEDER. Yes, I agree with that. I meant to express that idea, as a matter of fact. Maybe I did not do it well, but that is the thought I had in mind. I hate, however, to jump into big production plants right at this juncture.

Mr. INDRITZ. And yet at the same time one way of measuring the progress that has been made in research and in the application of the research is actually to build a plant and find out how it operates. For example, you indicated that the Badger-Hickman still operates very well on a small scale but when it is enlarged it does not operate quite so well.

Dr. SCHROEDER. Right. Let us look at that question just a little bit. I would consider the Badger-Hickman unit as we have now operated it, 25,000 gallons a day, an adequate pilot plant unit. Now the question comes, supposing this 25,000-gallons-a-day unit is successful. Do you want to then expand that into a million gallons a day to furnish some city water? This I think becomes a purely economic question. Does it furnish the water to the city at the lowest cost? I feel that way because I think once we have a 25,000-gallons-a-day unit in operation that we can then analyze the costs with a reasonable degree of accuracy, and perhaps we can get a number of people to agree what those costs will be. The strange part of this is that even if you took this 25,000-gallons-a-day plant and you said, "Now we have that operating properly. Now we have projected costs. If we make a million gallons a day, we project the cost as so and so. Let's build the plant to actually see whether those costs can be achieved." I very much doubt that you can improve your accuracy of estimating to any great extent, because even after you have this plant built and operating I doubt if people would agree in detail on just what that water costs.

May I point to a number of examples. Do you know what a barrel of oil is worth or a ton of steel is worth, or can you get people to agree on what a ton of steel is worth? When a steel company comes over and appears before Congress they say it is worth so much, and other people say it is worth so much, but nobody agrees.

Mr. JONES. It depends on whether you are putting it into a stockpile or taking it out.

Dr. SCHROEDER. Yes. I often wonder on a process like a distillation process, which is well known and where the items of equipment are somewhat standardized, like pumps and heat exchangers, and so forth, once we have the process well in mind and we know the details of the operation, whether we can arrive at reasonable cost figures and whether you can improve those cost figures much by building a big plant or not. I question that.

Now let us turn around and look at something else. Let us look at the membrane process, in which programs we have never really had a large-scale plant, never had anything so big perhaps as 100,000 gallons a day. Is that right, Mr. Jenkins?

Mr. JENKINS. The largest existing plant is about that size. The plant under construction in South Africa is for about 3 million gallons.

Dr. SCHROEDER. Well, I would say that if you have never had a plant of 100,000 gallons a day I think perhaps you would be justified in building one to cement your procedures and your cost estimates as far as you could. I would not go much more than that, though.

Mr. JONES. On the basis of determining cost factors and not in the field of trying to develop a pilot plant just for demonstration purposes?

Dr. SCHROEDER. That is correct.

Mr. INDRITZ. Would you advocate that attention be given to the possibility of achieving a double purpose from a particular process: for example, combining production of water and power or the production of water and fertilizer, or other marketable product that might be made with the equipment?

Dr. SCHROEDER. I think that is a fine way to go about it without costing anybody a whole lot of money. For instance, take a lot of these modern, high-pressure powerplants, particularly some which might be furnishing processed steam for various operations. Now, they have a pretty good makeup requirement for fresh water. Oftentimes they distill this water, and there, if you could get a tie-in and build a plant to furnish this water for boiler purposes, for example, I think that is a wonderful idea. They have to pay for it anyway. They probably would be willing to come in on a development like that, and you could have perhaps both Government and industry contribute to such a development. It is economical in every sense.

Mr. JONES. I believe we had an example of that yesterday, the Morro Bay steam generating plant, which has its own distillation unit and is operated by the Pacific Gas & Electric Co., which cost $44 million. The Federal Government granted the company a $20 million accelerated tax amortization, a rapid tax writeoff. So I think the Government has been pretty generous. Here is a $20 million tax writeoff, and this whole saline water program is going to cost only $10 million in 13 years. Notwithstanding this $20 million writeoff all in one plant, we are not getting the benefit of it other than finding out that they are getting water from the operation of that steam generating plant to make electricity.

Mr. INDRITZ. Dr. Schroeder, have you had experience in heading a research operation somewhat comparable to the saline conversion program?

Dr. SCHOEDER. I headed the synthetic fuel program in the Bureau of Mines.

Mr. INDRITZ. That was a Government program?

Dr. SCHROEDER. That is correct.

Mr. INDRITZ. In connection with your experience in that field, have you any suggestions to the committee as to how the Office of Saline Water program might be aided or its work expedited or improved?

Dr. SCHROEDER. Well, the synthetic fuel program that was in the Government, and still is in the Government, as a matter of fact—the total operation was a Government operation; that is, we hired the necessary engineers and built the plants and operated the plants. We operated that program out of Washington. Annual expenditures, I guess, ranged from about 5 or 6 million up to perhaps 10 or 12 million a year. We had a fairly small force here in Washington. We had about 5 or 6 technical men and some clerical people and stenographic people. The operation of that program was no great burden with a relatively small staff here in Washington. I have noticed quite a difference in the way that Mr. Jenkins and his staff operate and the way the synthetic fuel staff operated. Mr. Jenkins, in accordance with the law, does practically all of his work by employing private agencies, and I do not want to criticize that in any way. I think it is an excellent way to get work done.

It is, however, a fact that it means that a lot of contracts must be written and a lot of work must be followed quite closely. It means that his technical staff is pretty well tied up with writing contracts, trying to keep the redtape out of the way of people who are doing the work. I have always had a feeling from what contact I have had with them that they are pretty hard pressed just by paperwork. I have felt from time to time that they should have a little more time to devote to actually following the technical progress of the work. I do not think they have really got a staff that is adequate to do that on the basis of the present people that they have. I have not attempted any detailed examination, and I do not know whether I have any right to attempt a detailed examination. These are just more or less off-the-cuff ideas that have grown as I have tried to work.

Mr. JONES. Doctor, I think Mr. Jenkins will or did in substance agree with you yesterday in acknowledging that he could perform a greater service if he had more technical people. As a matter of fact, he related his experience in trying to find someone to fill a vacancy that is qualified to do the work, and finding qualified people is the major task. So I think your observation concurs with the thinking of Mr. Jenkins. Is that not right, Mr. Jenkins?

Mr. JENKINS. Yes, sir; I agree.

Mr. INDRITZ. Dr. Schroeder, you mentioned the need for a survey of future water requirements in order to compare what the costs might be for fresh water as against the costs of desalinization. Do you think that that type of survey would also encourage the private companies and manufacturers, that are interested in making equipment for desalinization, to engage in further research and in developing their processes?

Dr. SCHROEDER. It might or it might not. I am not sure just what this thing would lead to. If it showed, for example, that in certain areas these mechanical processes or chemical processes could compete with other sources of water, I am sure that it would encourage a sharp development in this direction. However, it might show the contrary. I think if this thing is 10 years off that private industry will wait a while before they go into it to any great extent, and that perhaps is the virtue of this saline water program. Several years ago, 5 years ago, there was no private organization that was interested in putting money into a long-range development like the evaporation of seawater or the reclaiming of brackish water. Yet it is certain if we are going to solve this problem it is not a few years' job as we see it; it is a longtime operation, and I think the Government was justified in going into it from exactly that angle. Whether the survey I am suggesting would immediately increase the private interest in this thing I would think would depend on the results of the survey. It might.

Mr. INDRITZ. It would at least give the private companies and industry a much better idea of what the situation is?

Dr. SCHROEDER. I think so. Yes, I am sure of that.

Mr. INDRITZ. Do you think that there is sufficient interest in private industry at the present time to warrant expansion of the efforts of the Office of Saline Water to secure cooperative arrangements with the companies that are interested in particular aspects of research, so as to broaden the scope of the Office's research?

Dr. SCHROEDER. Well, I do not know too much about the details of their contracts, but it seems to me that they have a number of very competent organizations to help them on this program, and I also feel that they have these organizations to help them at relatively low cost to the Government. I think some of these organizations put their effort in because they felt that this was a good thing and perhaps it offered possibilities for the future. Whether they can do any more in this direction or not, I do not know. I have talked to people who have complained bitterly that they work at too low a cost for this organization already, so this is a question. Whether they will put more effort into it or not, I do not know.

Mr. JONES. Doctor, you have observed the activity of the Office of Saline Water. If you were director of that Office and received a million dollars a year to carry out the activities and responsibilities of that office, what percent would you devote to basic research?

Dr. SCHROEDER. That is a tough question.

Mr. JONES. The reason I ask that question is that these programs in basic research must have some regular appropriation. They cannot be going on one day and cease the next. They have to be constantly worked at. So in order to come up with a long-range basic research program that will satisfy the objectives that you have placed before the subcommittee, it seems to me that it should be necessary to arrive at what percent we are going to use of the total amount appropriated for basic research.

Dr. SCHROEDER. It is a very good question, and I think anybody who is administering a program like this is torn between a couple of de-

sires. One is that as a Government agency you are not pressed by the competitive aspects of business. Therefore, you feel you ought to go forward with the basic research program, and that you will stimulate this business by supplying information which other organizations cannot afford to accumulate. On the other hand, I think a Government research agency has to face its board of directors once a year, just like private industry does, and the board of directors is the Bureau of the Budget and the Congress. The law states that one of the objectives of this program is to produce fresh water at low cost. Also, I think anybody who is running this program likes to come to you and say, "We are making progress, and our progress is measured by these results." So the result is that he has to use the best judgment he can with respect to the distribution of these funds.

Mr. JONES. Of course, I understand that you are not informed of all the details of the operation of that office, and I did not ask you that question to cause any embarrassment or to question the good judgment of Mr. Jenkins, who is now operating that Office. But since you are one who is learned in that area I thought maybe you could give us some general notion as to what percent would normally be utilized for basic research.

Dr. SCHROEDER. I think most people in industry would consider perhaps 10 percent of their budget as a perfectly reasonable figure for basic research.

Mr. JONES. That would be just 2 percent more than the amount appropriated by the Federal Government for all research purposes, which is 8 percent.

Dr. SCHROEDER. Eight percent on all Government research?

Mr. JONES. I believe Dr. Waterman, of the National Science Foundation, testified before this committee some time ago, that 8 percent was the amount.[7] Yet in the saline water program the total appropriation for fiscal year 1958 was $725,000, but only $25,000 was expended by the Office of Saline Water for basic research.

Dr. SCHROEDER. It is a little more now, is it not?

Mr. JONES. Here is what they have been doing, Doctor. These are all figures in basic research annually. In 1953 they had $22,400; in 1954 they had $46,300; in 1955, $27,200; in 1956, $54,200; in 1957, $37,500; and in 1958; $25,000. Now, it seems to me, from the standpoint of total dollar volume for the work of the Office of Saline Water, that its basic research is being retarded. Do you think that is a very healthy situation for the future of the program?

Dr. SCHROEDER. I think I would favor a somewhat greater expenditure of funds for basic research than shown here.

(The figures referred to were furnished by the department and are as follows:)

[7] See footnote 5, supra, p. 68.

*Research and development programs, Office of Saline Water, Department of the Interior*

| | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 |
|---|---|---|---|---|---|---|---|---|---|
| Estimates to the Department: | | | | | | | | | |
| Basic research | | | | $35,000 | $46,300 | $35,000 | $54,200 | $37,500 | $50,000 |
| Applied research | | | | 283,800 | 253,700 | 230,000 | 213,800 | 185,700 | 400,000 |
| Development engineering | | | | | | 35,000 | 217,000 | 210,800 | 519,000 |
| Administration | | | | 81,200 | 100,000 | 100,000 | 115,000 | 166,000 | 190,000 |
| Total | | | | 400,000 | 400,000 | 400,000 | 600,000 | 600,000 | 1,159,000 |
| Estimate to Bureau of the Budget: | | | | | | | | | |
| Basic research | | | | 35,000 | 46,300 | 35,000 | 54,200 | 37,500 | 50,000 |
| Applied research | | | | 283,800 | 253,700 | 230,000 | 213,800 | 185,700 | 400,000 |
| Development engineering | | | | | | 35,000 | 217,000 | 210,800 | 519,000 |
| Administration | | | | 81,200 | 100,000 | 100,000 | 115,000 | 166,000 | 190,000 |
| Total | | | | 400,000 | 400,000 | 400,000 | 600,000 | 600,000 | 1,159,000 |
| President's budget: | | | | | | | | | |
| Basic research | | | | 35,000 | 46,300 | 35,000 | 54,200 | 37,500 | 50,000 |
| Applied research | | | | 283,800 | 253,700 | 230,000 | 213,800 | 185,700 | 400,000 |
| Development engineering | | | | | | 35,000 | 217,000 | 210,800 | 519,000 |
| Administration | | | | 81,200 | 100,000 | 100,000 | 115,000 | 166,000 | [1] 190,000 |
| Total | | | | 400,000 | 400,000 | 400,000 | 600,000 | 600,000 | 1,159,000 |
| Appropriations: | | | | | | | | | |
| Basic research | | | | 22,400 | 46,300 | 27,200 | 54,200 | 37,500 | 25,000 |
| Applied research | | | | 83,600 | 253,700 | 232,800 | 213,800 | 185,700 | 275,000 |
| Development engineering | | | | | | 35,000 | 217,000 | 210,800 | 300,000 |
| Administration | | | | 69,000 | 100,000 | 105,000 | 115,000 | 116,000 | 125,000 |
| Total | | | | 175,000 | 400,000 | 400,000 | 600,000 | 550,000 | 725,000 |
| Obligations (research and development): | | | | | | | | | |
| Federal laboratories | | | | | | 15,460 | 49,042 | 50,000 | 60,000 |
| Educational institutions | | | | 46,690 | 69,427 | 142,060 | 59,985 | 41,282 | 50,000 |
| Nonprofit organizations | | | | 3,000 | 1,350 | 14,000 | 79,878 | 9,000 | 10,000 |
| Private contractors | | | | 65,215 | 260,591 | 149,341 | 315,943 | 309,018 | 480,000 |
| Total | | | | 114,905 | 331,368 | 320,861 | 504,848 | 409,300 | 600,000 |
| Obligations (overhead) | | | | 57,643 | 67,077 | 77,397 | 91,516 | 100,663 | 125,000 |
| Total obligations | | | | 172,548 | 398,445 | 398,258 | 596,364 | 509,963 | 725,000 |

[1] This amount was prorated, 9 percent to basic research and 91 percent to applied and development.

DEFINITIONS

Basic research is research having as its primary objective the increase of knowledge in science, or more specifically the obtaining of a fuller understanding of the subject or phenomena under study.

Applied research is research directed toward making specific scientific principles usable in engineering practice. It is the practical application of basic research to the development of conversion processes.

Development engineering relates to the systematic use of scientific knowledge directed toward the production of devices, methods, or processes, including design engineering, construction, and operation of pilot plants.

Applications engineering: Authority of the Office of Saline Water does not extend beyond development of pilot plants described under development engineering and this Office does not suggest a definition for applications engineering.

NATURE OF PROJECTS

(1) The projects classified under basic research consisted of investigations of the minimum energy requirement for separation of fresh water from sea water, new principles for possible application to demineralization, new ion-permeable and osmotic membranes, parameters affecting freezing of solutions, precipitation of salts and scale deposition in evaporators.

(2) Projects involving applied research included investigations in such fields as distillation, freezing, electrodialysis, "osmionisis," solvent extraction, solar energy, and certain combinations of nuclear-power reactors with conversion methods.

(3) Development engineering projects deal with the design, fabrication, and testing of such pilot-plant units as the Badger-Hickman rotary vapor compression distillation unit, the LTV multiple-effect distillation unit, and several different types of solar distillation models.

LIMITATIONS OR RESTRICTIONS

No limitations or restrictions have been imposed by the Department of the Interior, the Department of Defense, the Bureau of the Budget or the President in connection with the making of the preparation of the appropriation requests.

Mr. JONES. Doctor, have you had occasion to study the public law from which grew the Federal responsibility?

Dr. SCHROEDER. I have read it some time ago, but I am familiar with it.

Mr. JONES. Do you have any recommendations to make relative to its improvement or how we can perfect the law to be more useful?

Dr. SCHROEDER. No. My impression is that the law is fairly well written. My feeling is that the Office of Saline Water could do a better job if they had a little more liberal allowance for the Office itself.

Mr. JONES. For the management?

Dr. SCHROEDER. For the management; yes, sir.

Mr. JONES. There is a restriction of 20 percent, I believe, for administration. In your opinion would it be wise to increase the amount authorized for administration and remove the 20-percent limitation on management?

Dr. SCHROEDER. You would not want to remove it completely, but I think a substantial increase in that would be helpful, and I really think it would give you more for your money than you are getting now.

Mr. JONES. There is a limitation on the use of Federal laboratories up to 25 percent of the total amount. Do you think that restriction is too limited?

Dr. SCHROEDER. I doubt that, because I do not know as there is any special talent in the United States Government that they have to turn to to get work done. They can employ outside talent on contract to get that work done, so I would not think that was too severe a limitation.

Mr. JONES. In other words, the practice now employed of obtaining this work by contract would be just as satisfactory as having Federal laboratories to do this work?

Dr. SCHROEDER. I would think so.

Mr. JONES. There is the other limitation of making the apportionment equally per annum. Do you think that limitation should be removed?

Dr. SCHROEDER. Ten percent of the total authorized?

Mr. JONES. Of the total amount authorized in the program.

Dr. SCHROEDER. That means you are limited to a million dollars in any one year. Yes, I think that limitation could be quite a handicap, particularly as you move into building fairly large-size pilot plants. It might mean that you would have to stretch a pilot-plant construction out over 2 years instead of doing it in 1 year.

Mr. JONES. It would make it more expensive?

Dr. SCHROEDER. Make it more expensive; yes.

Mr. JONES. Doctor, thank you very much. You have been quite helpful to the subcommittee, and we are deeply indebted to you for taking your time and giving us the benefit of your vast experience and knowledge on this subject.

Dr. SCHROEDER. I enjoyed being here.

Mr. JONES. It was good to have you, sir.

We will continue with the Department of Interior witnesses. Next is Mr. Strobel, Chief, Branch of Engineering, Office of Saline Water.

## STATEMENT OF J. J. STROBEL, CHIEF, BRANCH OF ENGINEERING, OFFICE OF SALINE WATER, DEPARTMENT OF THE INTERIOR

Mr. STROBEL. Mr. Chairman and ladies and gentlemen, yesterday in talking about the research and development that we have been working on in the Office, Dr. Gillam covered some of the work on membranes. I will discuss briefly some of the research and development in several other areas.

Use of freezing as a conversion process is a promising approach for getting fresh water from salt water. One of the very great difficulties has been that when the ice crystals are formed, which are in themselves pure water, they have trapped or included residual brine with those ice crystals, and that has held back development of a feasible process. However, the Carrier Corp. has been working on a freezing process. It is actually a combination of evaporation with freezing, and they have now been able to produce fresh water from sea water in a continuous manner at a rate of about 100 pounds per hour of ice in some experimental equipment that they have developed. We will show the first slide (chart 1).

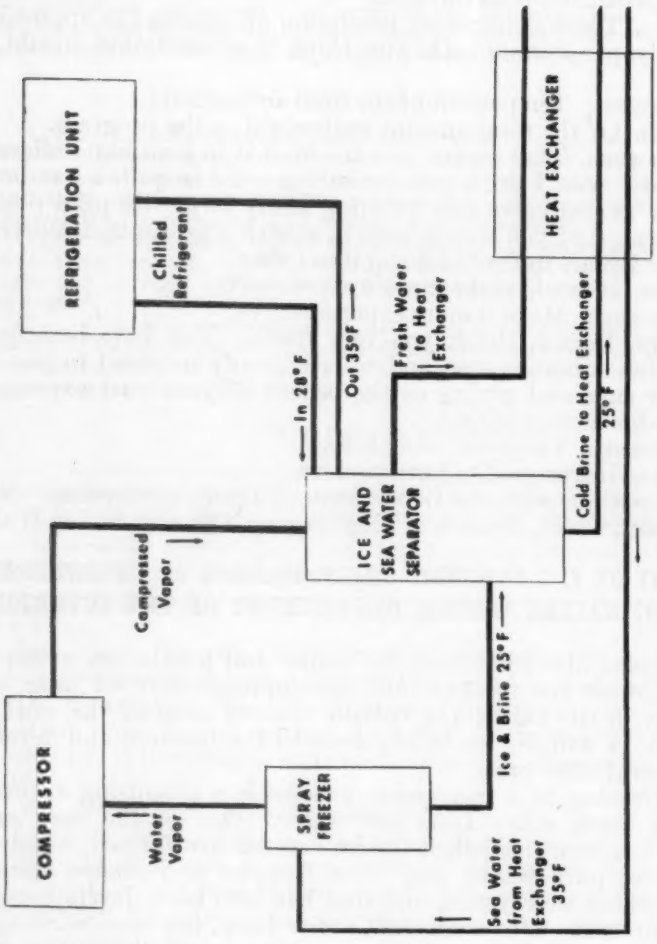


CHART 1.—Freeze-evaporation process.

This is a diagram of the process that they are working on. The sea water is brought into a low-pressure or vacuum chamber, where part of the water evaporates and forms an ice-brine slush. This is taken from the bottom of the freezing chamber over a separation column, which is simply a countercurrent wash column. The ice and brine come in the bottom. The ice gradually floats to the top and a small amount of fresh water comes down from the top and washes that entrapped brine away. The vapor which is formed, which is also a pure water vapor, in the evaporating process is condensed and used to help melt the ice product. Thus, the melted ice and condensed vapor is the fresh-water product.

The two critical parts of the process are the freezer and the separator.

The next slide shows these two pieces of equipment in operation. This is the freezing chamber, and this is the top of the wash column,

CHART 2.—Experimental freezer and separator in operation.

which extends down through the floor about 12 feet. Right here is the ice coming out of the top of this column. These two experimental units are only a part of the process. It was a part of the development program to look into those first two steps initially. As far as the Carrier people have gone, they have not found any reason to believe that this process will not be technically feasible. As I say, its two critical steps have been worked out fairly well. They are now continuing to operate the experimental equipment for additional data and are making preliminary designs and studies on the next step of the program, that is, some pilot-plant operation which would incorporate all parts of the complete freezing and evaporation system.

I will mention just briefly several other contracts in this general area of freezing. We have been carrying out some rather basic research on a zone refining technique or adaptation of the zone refining technique used on metals. In this adaptation the frozen zone is passed along a column of salt water so that the impurities are concentrated at one end of this column of water. This has been done and fresh water obtained, but it remains to be seen if an economic method can stem from that idea.

Just recently we have executed a contract with Cornell University for some research on a system of direct refrigeration, using a liquid hydrocarbon refrigerating material like butane, which would be evaporated right in the contact with the sea water and form ice without heat exchange surface. This is a small initial research contract to determine just how hydrocarbons will act under these conditions and what sort of ice formation you get. In this process also will be incorporated some countercurrent washing system to free the ice of the remaining brine.

Solar distillation is another area in which there has been some research and development. Solar distillation should have some application, we believe, under certain conditions. For example, in the United States if there were small, practical solar stills available I think they could be used in many areas, such as desert areas, residential use, where there is brackish water available but no fresh water; also in some of the seacoast areas, again residential use, where fresh water is hard to get. There are other special applications where solar stills could be useful. There are probably more applications for solar distillation in some of the overseas areas, and it may be possible for larger solar stills to compete with other conversion processes in some of those areas.

All of the workers in this field have agreed that the best approach to solar energy use for sea weater conversion is to concentrate on simple type solar stills that will last a very long time and have low maintenance and operating costs.

The work that we have sponsored has resulted in four different designs. Dr. Löf proposes an on-the-ground basin type still covered by a sloping grass roof. Dr. Telkes, of New York University, has proposed several stills, one a tilted still and another a multiple-effect type, both of which use a wick material. The Bjorksten Laboratories have concentrated on use of plastic materials in this application and have developed a design they call an envelope-type still.

The DuPont Co. has been looking into solar distillation in cooperation with our office and have an idea for using an air-supported plastic film as a cover for one of these basin-type stills.

This next slide shows one of the stills that they have operated. These stills are about 25 feet long and about 2 feet wide. This is a shallow pan of a black plastic material, polyethylene, where salt water is evaporated. Over the top you see the two air-supported plastic covers. It takes very little air pressure to keep these supported, and you get away from the necessity of a framework. The water evaporates from the shallow pan and is condensed on the inside surface of the plastic film and runs down the sides to the fresh water troughs along the side.

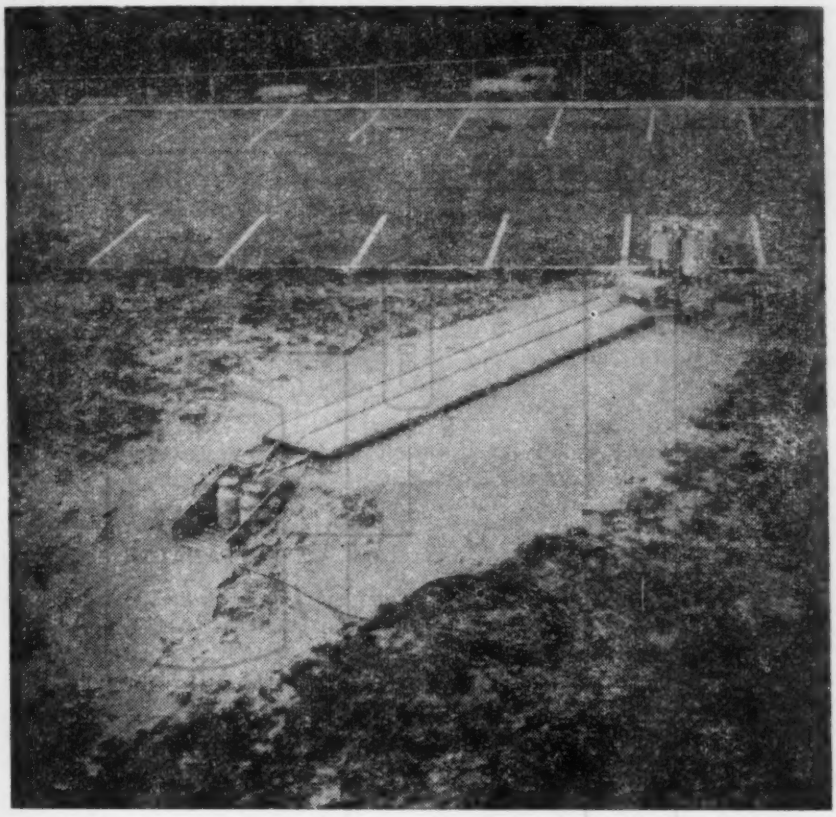

CHART 3.—Experimental solar still with air-supported canopy (Du Pont).

With all these various ideas being worked on, and development of designs that should be tested, we believed that the best next step was to set up an integrated test and development program at a seashore location where various prototype or small pilot-plant solar stills could be built and tested. This has been recently done through a contract with the Battelle Memorial Institute; they are going to carry out that type of program for us adjacent to their exposure test station near Port Orange, Fla.

The last process which I wish to mention is the work that has been going on at Texas A. and M. Research Foundation on the solvent extraction method. You can use certain organic solvents to mix with

salt water which will pick up some of the fresh water from that solution and leave the salt remaining in the original salt solution. This solvent has to be such that it does not mix with the salt water, so that you then have a two-layer separation, with the solvent containing the fresh water in one layer and the remaining brine in another layer. The solvent phase is separated and the temperature changed in order to make it release the fresh water.

This next slide shows a schematic diagram of how that process would operate. This would be the column wherein the solvent and salt water are mixed. Then when the solvent picks up some water it is taken off the top and the temperature changed. When that temperature is changed, its ability to hold this water decreases, so that you get back some fresh water in the process in this separator; the solvent is then taken back to be reused and pick up more fresh water from the salt water.

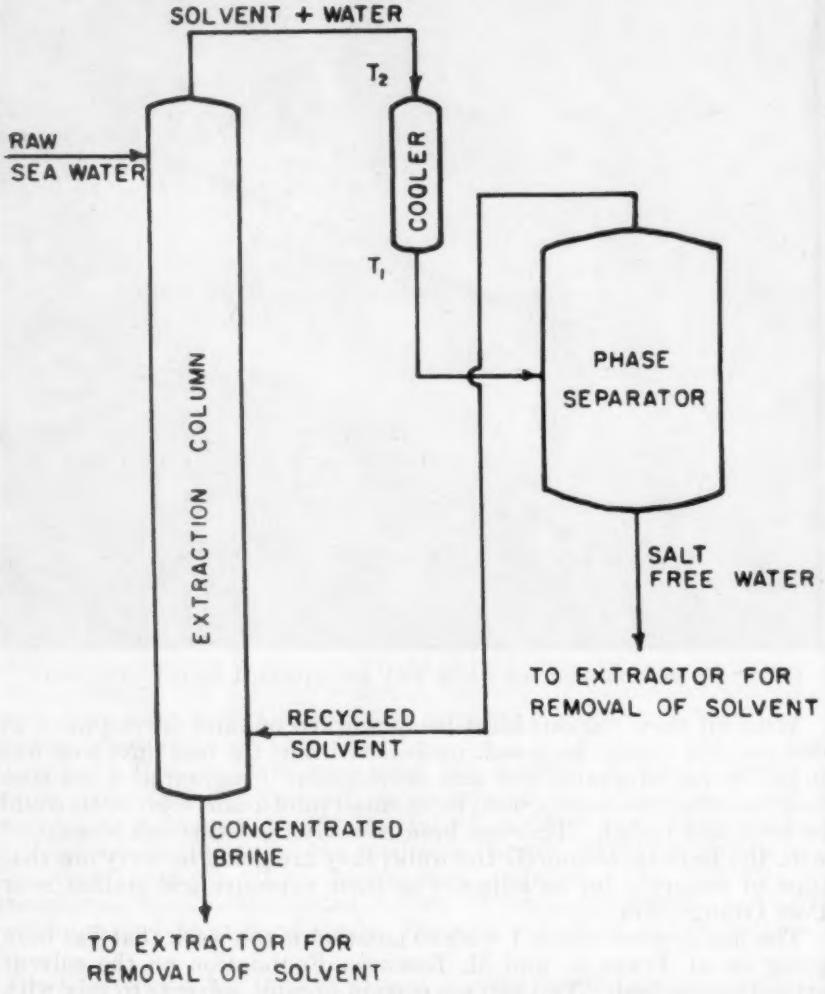


CHART 4.—Diagram of solvent desalination process.

It takes solvents with some rather unusual properties to do this, and the research to date has concentrated primarily on finding the proper solvents and learning how to make them. The Texas A. and M. has screened several hundred organic solvents in an attempt to see which ones might be the best and to get an idea of how to make ones that are better. I might mention that one of the best solvents they found is an amine type, an ethylbutylamine. When mixed with sea water, it picks up about 30 percent by weight at 30 degrees centigrade. Then when that temperature is raised to 75 degrees centigrade it releases all of that fresh water except 13 percent.

At the present time the Texas A. and M. group is continuing their search for better solvents, to make the process more efficient, including synthesis of solvents which they think will be efficient. They also have built and are operating a small laboratory model of the whole solvent extraction process on a very small scale. They are using this to evaluate further the solvents and are also concentrating on the application of this process to brackish water. From what they have done so far it appears that the process may be most useful on brackish water.

Mr. JONES. Thank you, Mr. Strobel.

Mrs. Granahan?

Mrs. GRANAHAN. No questions.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. Mr. Strobel, in November of 1957, upon conclusion of the saline water symposium, the Committee on the Freezing Processes stated in its report that—

**There is a consensus of opinion that this program—**

meaning the freezing process program—

**should be accelerated and that the financial support be appreciably increased * * * that the program of desalting water by freezing be definitely enlarged by both personnel and research investment.**

What has been done, since the issuance of that report of November 1957, to carry forward with those recommendations?

Mr. STROBEL. I think it is reflected to a considerable extent in the breakdown of funds in the 1959 budget request. I mean we are giving greater attention to the possibility of freezing than we have in the past, primarily because we can see now some possibilities in the system since the problem which has held us back—that is, the problem of getting rid of the brine—seems to be headed toward solution.

Mr. INDRITZ. How much of your funds was allocated for the freezing process during the year prior to November 1957?

Mr. STROBEL. I would have to supply that from our record.

Mr. INDRITZ. And could you also supply the amount of the funds allocated for it since then, so we can see the increase that you have reference to?

Mr. STROBEL. Yes, we can do that.

Mr. INDRITZ. And could you also give us a list of any contracts which have been let for that process since November 1957?

Mr. STROBEL. Yes.

(The information requested was supplied as follows:)

DEPARTMENT OF THE INTERIOR,
OFFICE OF SALINE WATER,
*Washington, D. C., April 18, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee*
*of the Committee on Government Operations,*
*House of Representatives, Washington, D. C.*

DEAR MR. JONES: In accordance with the request of Mr. Phineas Indritz, April 16, 1958, the following information is forwarded:

(*a*) Funds contracted for freezing processes since the saline-water conversion symposium, November 4–6, 1957:

| | |
|---|---|
| Cornell University (direct freezing) | $14,875 |
| Carrier Corp. (freeze-evaporation) | 48,070 |

(*b*) On the basis of budget estimate of $825,000 for fiscal 1959, the estimated amount to be used on freezing processes is $95,000.

Sincerely yours,

DAVID S. JENKINS, *Director.*

Mr. INDRITZ. Have any additional personnel been assigned to that work?

Mr. STROBEL. There have been no additional personnel assigned in out office.

Mr. INDRITZ. At the time of the symposium, the Solar Distillation Committee stated that "Pilot-plant work should be undertaken to get sound engineering data for later full-scale installations" and described it as "a neglected area at the present."

Now, what has been done since November 1957 to make it a little less neglected area?

Mr. STROBEL. I covered that to some extent in my talk just now. Since that time we have contracted with Battelle Memorial Institute to establish the integrated solar development program in an actual seashore location.

Mr. INDRITZ. Is that the only contract that has been made for solar distillation work since November 1957?

Mr. STROBEL. I would not be sure of that without looking at the record. I think we have amended several of our contracts since that time.

I might say that you will notice that each committee at the symposium recommended that their own field receive more attention than it had in the past, which adds up to not being able to follow such recommendations except to the extent we have funds available. In other words, each committee at the symposium felt that their work should have more funds and more attention.

Mr. INDRITZ. Secretary Aandahl, who testified yesterday, indicated that Secretary Seaton was going to ask for a supplemental appropriation of an additional $530,000. How much more funds would be allocated to each of these processes?

Mr. STROBEL. I think that was covered yesterday in Mr. Jenkins' testimony, as I recall.

Mr. INDRITZ. Is there any work being done on separating the sodium from other salts in water?

Mr. STROBEL. The only place where we had a possibility of that is in some of the membrane processes. I would like to see if Dr. Gillam has some comment on that.

Mr. JONES. What is the question?

Mr. INDRITZ. Separating the sodium from other salts in water.

Dr. GILLAM. The separation of specific ions, like sodium ions from other ions, has been investigated to a limited extent by Dr. Gregor, of Brooklyn Polytechnic Institute, who was attempting to develop ion-specific membranes.

Some progress was made in that limited work. However, it was decided that at this time such a process appeared to be impractical and he should devote more of his attention to the development of ion-permeable membranes rather than concentrate on the separation of a specific ion, like sodium, from potassium or calcium.

Mr. INDRITZ. Thank you.

Mr. Strobel, have you personally gone to see the installations that you talked about?

Mr. STROBEL. Yes, I have.

Mr. INDRITZ. How often did you visit them to check on the progress that is being made?

Mr. STROBEL. As often as we believe it is necessary to do so. It varies with the particular process and the stage of development that it is in.

Mr. INDRITZ. Do you feel that sufficient personal inspections are being made of the various processes throughout the country, or that more personal inspection ought to be made in order to keep abreast of them?

Mr. STROBEL. I think the answer is that if the staff was somewhat bigger, we would do more than we have.

Mr. JONES. In other words, you agree with the observation made by Dr. Schroeder that if you were relieved of a great deal of your administrative details, you could devote more time to the pursuit of scientific inquiry?

Mr. STROBEL. Well, I am not sure I would put it just that way.

Mr. JONES. Well, put it your way.

Mr. STROBEL. I think Mr. Jenkins testified yesterday in his testimony that in the contract program we have, it is necessary that technical people carry out considerable amounts of the paperwork, because it is intimately involved with the results of the research. But if we had more people, it would make that percentage of time for each one less.

Mr. JONES. I see. Well, the sum total of your observation is we need more people to do more work; is that right?

Mr. STROBEL. I will agree with that.

Mr. JONES. Thank you very much, Mr. Strobel.

Is there any further observation, Mrs. Granahan?

Mrs. GRANAHAN. No.

Mr. ROMNEY. No, sir.

Mr. JONES. Mr. Allen Cywin.

## STATEMENT OF ALLEN CYWIN, FIELD REPRESENTATIVE AND MECHANICAL ENGINEER, OFFICE OF SALINE WATER, DEPARTMENT OF THE INTERIOR

Mr. CYWIN. Good afternoon, Congressman Jones, Mrs. Granahan, ladies, and gentlemen. I would like to touch on 3 or 4 of our more advanced distillation processes.

If, as I show slides, you have a particular question to ask about a particular slide, please do not hesitate to interrupt me.

Congressman Jones, in your opening statement yesterday, you mentioned the fact that sea water conversion dated back many years, and I assume you were referring primarily to the distillation process because this process dates back literally hundreds of years.

There are not very many large-scale sea water plants in the world today because of cost, so the first question to be answered in any program of this type is: "Can we ever reach economic goals with this particular process?" We asked some of the leading evaporator specialists in the world to study this for us.

The first slide I am going to show will depict what an optimum large-scale distillation plant might look like someday.

Slide, please. (Fig. 1.)

This is a page out of the report that was compiled by W. L. Badger. Mr. Badger took components of equipments that could be produced today, not quite in the size that he would need for this particular plant but large enough so that we could use available engineering and cost estimating data that we could rely on for cost estimating a large-scale water production plant.

This particular plant is for 17 million gallons per day capacity; 17 million gallons per day size using these equipments just happened to be a low point on the economic cost curve.

In order to get these optimum goals, we had to make certain assumptions, assumptions we cannot achieve right at this minute, right today. We had to assume that we could use ideal materials of construction, in this case mild steel. We had to assume we could operate scale free at little or no cost to the process. That is what we have assumed in this particular plant.

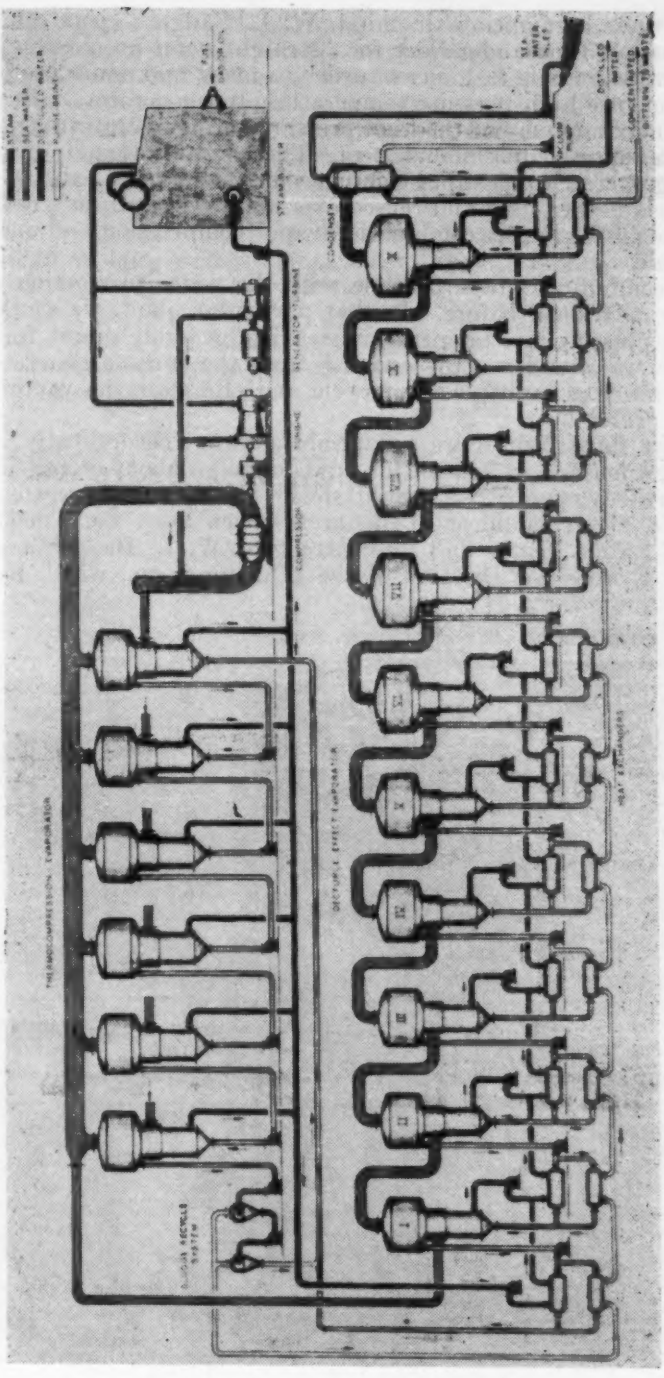

FIGURE 1.—W. L. Badger long tube vertical system.

With these assumptions in mind, W. L. Badger's costs came out to 40 cents per thousand gallons for a straight water production plant.

It operates in this fashion; in order to make maximum use of the fuel input, use high-pressure temperature and generators. In order to make maximum use of the high pressure and temperature steam we operate a vapor compression system. These evaporators [indicating] are being operated in a vapor compression system. The exhaust from this system is then used and reused over and over again in a multiple effect cycle. We have a combination vapor compression and multiple effect cycle.

Now, combining power for sale with the water production plant has been mentioned before. In that particular plant, we would use our high pressure and temperature steam to generate power for sale, and then we would use the exhaust from the turbine generator to exhaust into the multiple-effect cycle and eliminate the vapor-compression cycle.

Now we have proved we can produce water, theoretically, at 40 cents per thousand gallons. But how do we go about doing this?

We have to operate with mild steel. We have to operate scale free. We have some ideas in this area—when I say we, I mean the Office of Saline Water and its contractors, W. L. Badger and the Swenson Evaporator Division of the Whiting Corp., which has assisted in this project.

Next slide, please. (Fig. 2.)

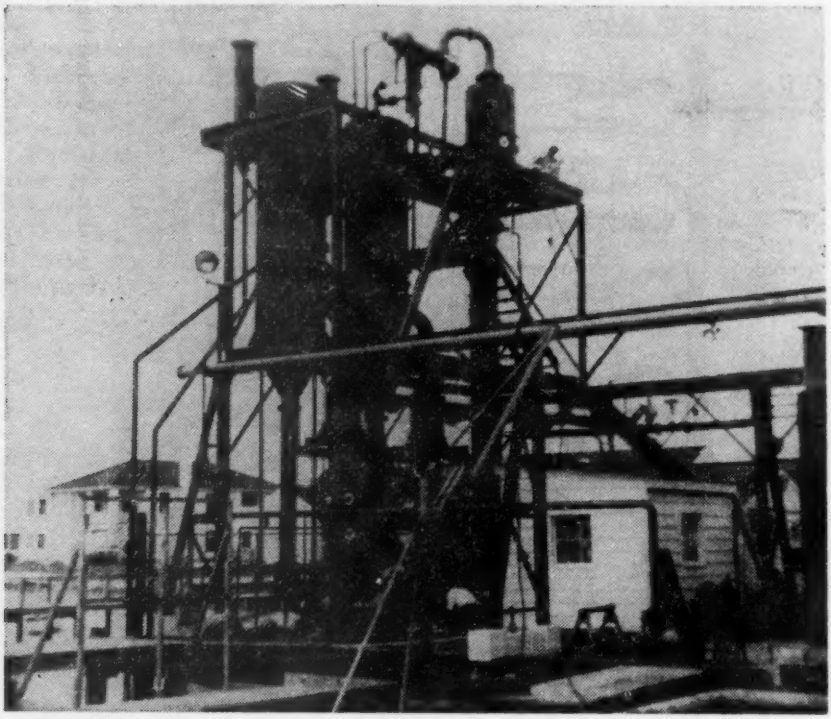

FIGURE 2.—Whiting Corp.-W. L. Badger & Associates long tube vertical test facility.

In order to prove whether or not we can operate the system as designed, we have constructed this experimental test facility down at Harbor Island, N. C. This is a rather large test tube, as you can see by the man welding up here [indicating].

This is our test evaporator, one evaporator over here. All the rest of this equipment is needed to concentrate the sea water and to heat the sea water so as to simulate any stage in that multiple effect cycle we saw on the previous slide.

As you saw on the first slide, the vapor-compression evaporators can be used in large-scale plants. They can also be used for small household stills or where electric power is readily available.

For some time now we have followed a development that we believe might prove very advantageous in the field of vapor compression, that is the Hickman centrifugal process.

Slide, please. (Fig. 3.)

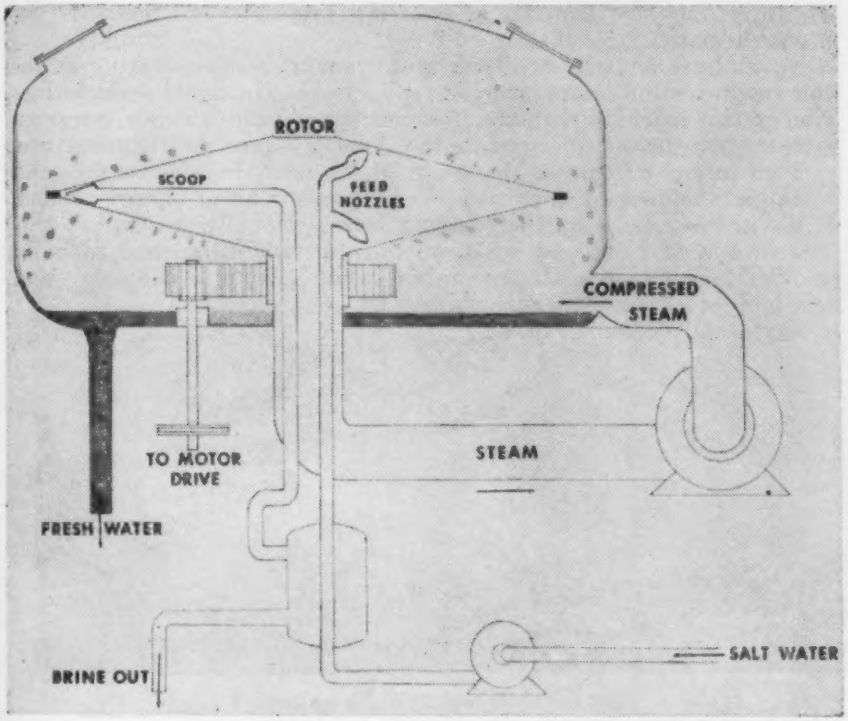


FIGURE 3.—Single Rotor-Hickman rotary still (schematic).

This is a cutaway of the single rotor, Hickman rotary still. It operates in this fashion. In the previous type of evaporation system, we used tubes. The steam was on one side and water on the other side.

In this type of evaporation system, we use flat disks, almost like pie plates. These disks are rotating. The sea water is fed in through a heat exchanger, straight through feed nozzles, onto these rotating disks. Centrifugal action forces the feed water into a thin turbulent film.

A part of the sea water vaporizes. The part that does not evaporate, which has the residue salts, is withdrawn in this brine blowdown pipe arrangement. The part that is vaporized is compressed and then condensed on the other side of the heat transfer barrier. When it condenses, it loses its heat of vaporation and thus reevaporates a similar amount of feed water on the other side of the heat transfer barrier.

Now we have achieved very high heat transfer rates in this piece of equipment. Relating this advantage and relating the magnitude of our achievement here, we should tell you that standard vapor compression evaporators are normally operated at 212° F. evaporating temperature. At this temperature, we scale badly.

Mr. JONES. Scale what?

Mr. CYWIN. We scale badly. We have found, however, that if we operate at low temperatures and pressures, less than 150 degrees, for example, we can operate for long periods of time without scaling. However, our heat transfer rates at low pressures and temperatures are depreciated.

So we have actually achieved heat transfer rates operating at the low pressures and temperatures that we need to mitigate scale formation in this machine that are 10 times better than a vapor compression evaporator operating with the same pressure and temperature.

That means we can use one-tenth of the heat transfer surface and a simpler compressor and with less compressor input energy needed.

We are penalized by the rotating mass. In order to exploit this system and find out just what we can do with it, we had to build another larger system that we might want to take to the ocean and test in a set of field experiments.

Next slide, please. (Fig. 4.)

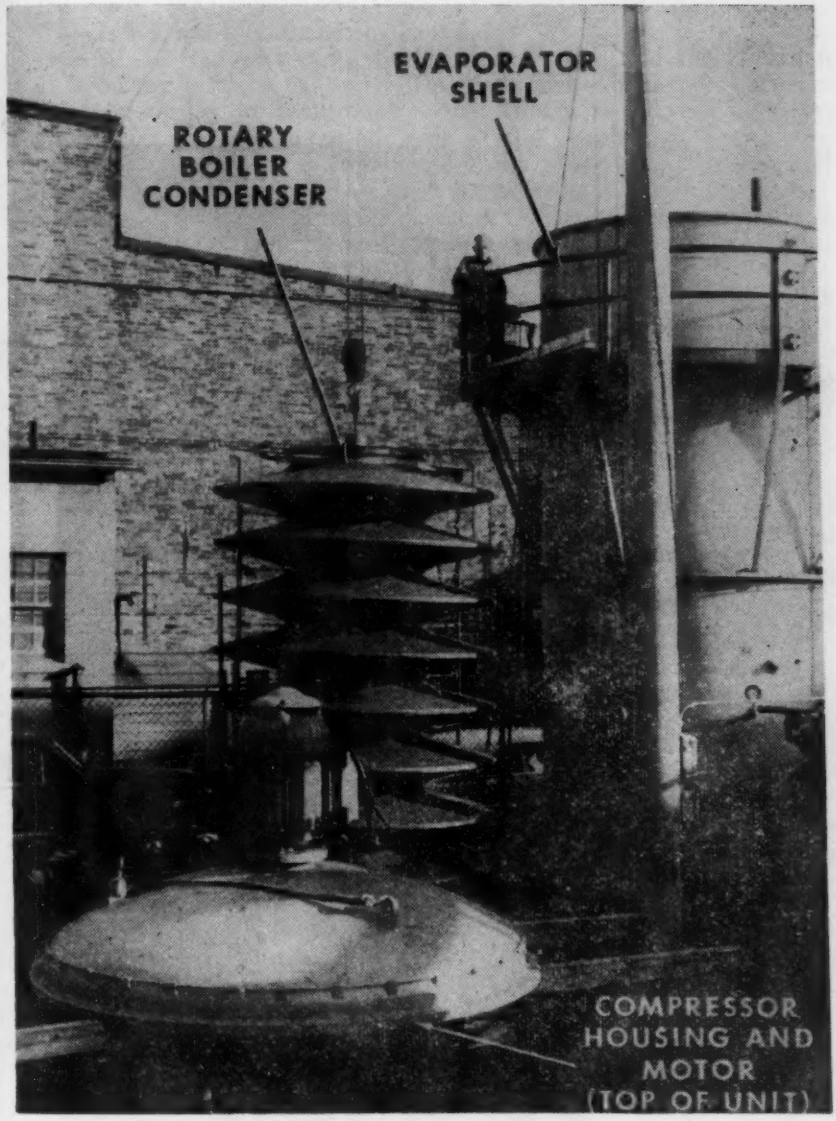


FIGURE 4.—No. 5 Badger-Hickman still.

This is the Hickman multiple rotor still designed at an optimum rate of 25,000 gallons per day. There are 8 sets of rotors as compared to the 1 set we saw before. They are also larger in diameter. These happened to be 8 feet in diameter. These rotors lift up and fit inside this evaporator body. This is the top, with the motor over here that operates the compressor that fits on top [indicating]. This unit has also recently been taken to Harbor Island.

Next slide, please. (Fig. 5.)

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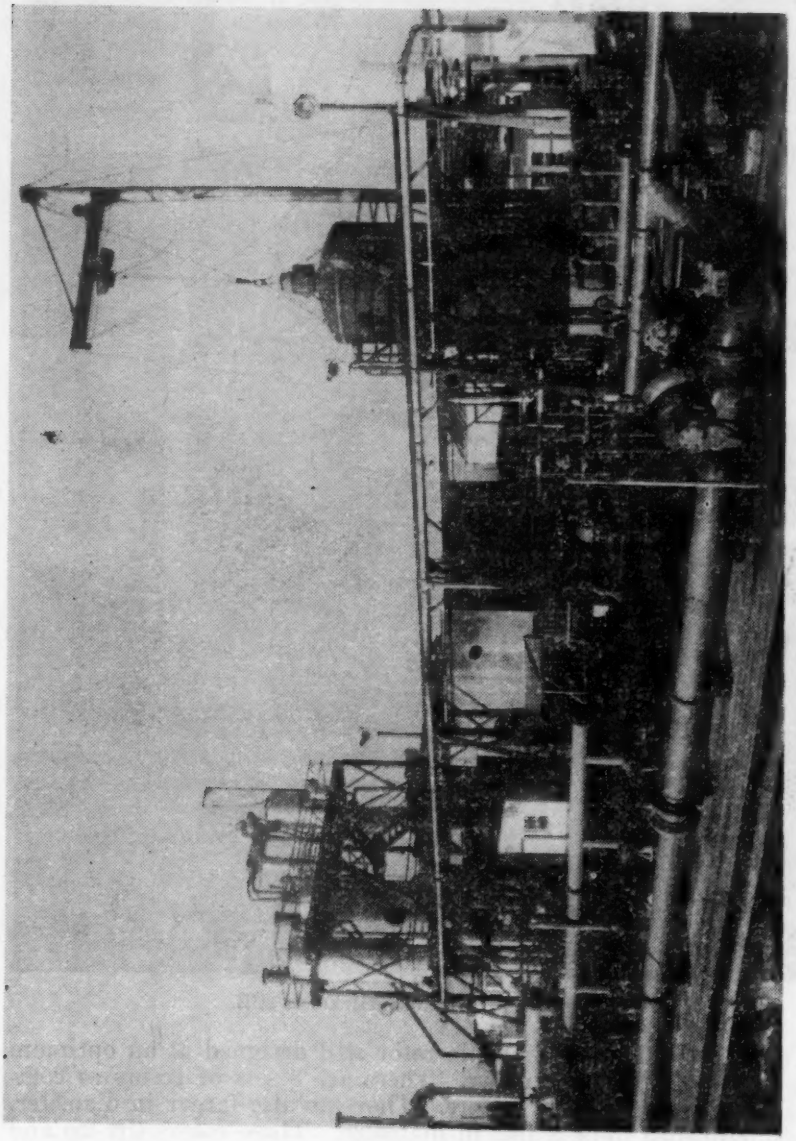

FIGURE 5.—Test evaporators at International Nickel Co. Laboratory, Wrightsville Beach, N. C.

This is Harbor Island as it looks today.

Our W. L. Badger test facility is on my right, and the Hickman still is on my left. A Navy still happens to be on test in between.

Now, yesterday we mentioned cooperation with private industry. I think that I should mention some of the people that have cooperated helping us to establish these two big pieces of equipment and set them in operating condition at this site.

First of all, the International Nickel Co. has allowed us the use of its facility rent free. It also furnishes us utilities at direct cost.

Secondly, the Bureau of Ships of the Navy Department had established a foundation slab at that site. This equipment is rather heavy and needs a good foundation. They had poured a slab for the purpose of testing their own equipment. We got permission from the Navy, of course, with no transfer of funds, to use a part of their slab. As you see, we are actually using most of it.

In addition, in order to build this experimental facility, we obtained from the Whiting Corp. the actual experimental evaporator at no cost to the project.

The other two evaporators we obtained at actual direct cost. We even got a major paint company to supply the paint free that went on this still.

On the Badger-Hickman side of the fence, the Badger Co. built this and tested it at very little overhead and no profit. Of course they are not equipped to extensively test a piece of equipment at a seashore site.

We now have the Battelle Memorial Institute field testing this piece of equipment down at Harbor Island and both machines are running and running well down there. Now, there is another type of evaporator system that has received very widespread commercial application at the present time. This is the flash system. Multistage flash units are being used for both marine and land requirements, right at the present time; and there are 2 or 3 manufacturers' representatives in the audience who I am sure would like to sell you a plant of that type right at this minute if you needed one.

There are aspects of the flash system, though, that have not been investigated. One aspect was the commercial design and optimum cost estimation for a low-temperature difference system.

There are places in the country that have just hot water available: for example, water at perhaps 100°. Places like the condensing systems of evaporating plants. San Diego Gas & Electric Co. has a plant right at Encinitas. They use the ocean for their condensing water.

There are other processing plants throughout the country, and the French have long advocated the use of ocean thermal differences for such a process.

The Griscom-Russell Co. just finished a study in which they designed a single-stage flash evaporator operating at low temperatures and at low-temperature differences.

Slide, please. (Fig. 6.)

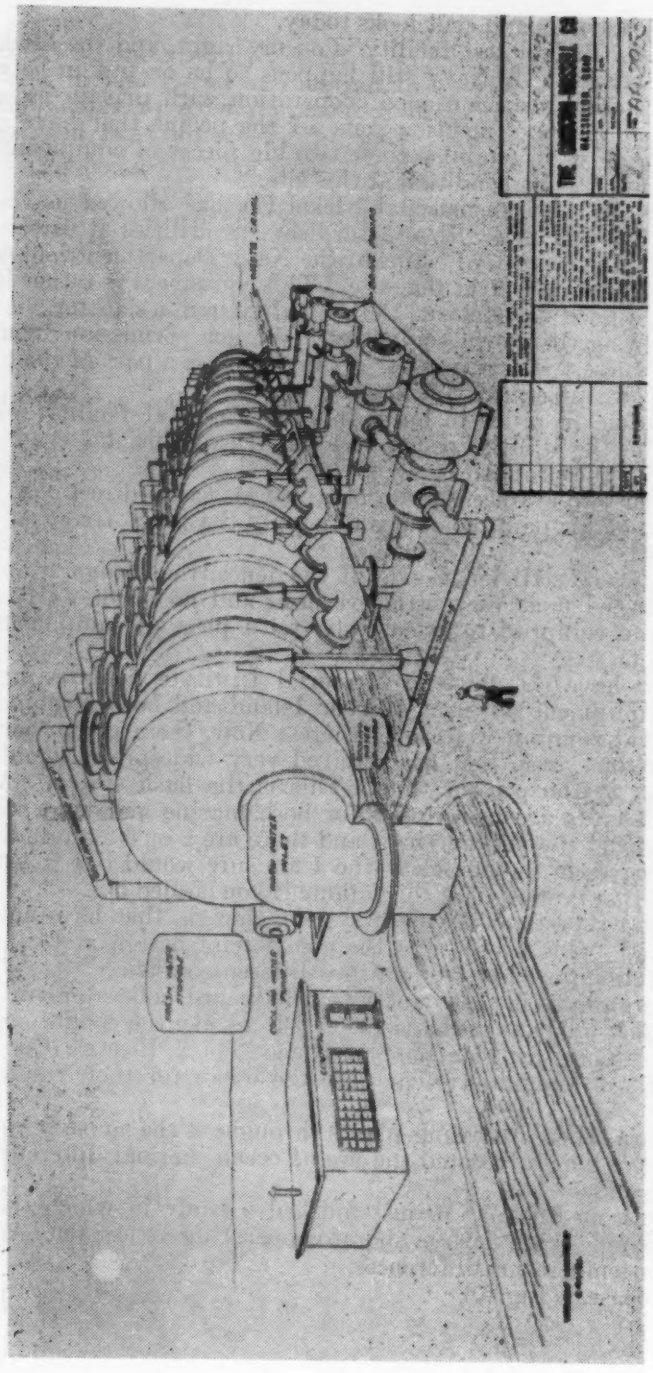

FIGURE 6.—Artist's conception of 10 million gallons per day flash distillation plant. The Griscom-Russell Co.

This is an artist's conception of a single-stage 10-million-gallon-per-day plant. It is 30 feet in diameter and approximately 360 feet long.

In strict accordance with our cost estimating procedure, the water from this plant turns out to be about $1.20 per thousand gallons. However, we had to assume that if we are ever going to use this plant any place, we would have to have warm and cold water right at the site. That is essential for this system.

Taking that into consideration and with a few minor other exceptions, the Griscom-Russell Co. reestimated the plant and in their view the water from this plant should turn out to be around 70 cents a thousand gallons.

Now, with all but the last plant in, all of our evaporation systems, we need large blocks of energy. For some time, nuclear energy has been suggested as a source, as a new source of energy supply. However, we all realize that nuclear power costs more than power that can be generated in conventional powerplants, at least today it costs more.

We decided to take another look at nuclear reactors, though; and in reviewing the situation, we felt that a nuclear reactor primarily generating low-temperature steam—I am talking about 212°—steam exhausted directly into the evaporator cycle, might, prove to be an economical method of obtaining a cheap source of energy for our evaporators.

Fluor Corp. and the Atomic Energy Commission and ourselves got together and selected reactors and evaporators that we thought might prove to be economical when combined with this type of system.

Slide, please. (Fig. 7.)

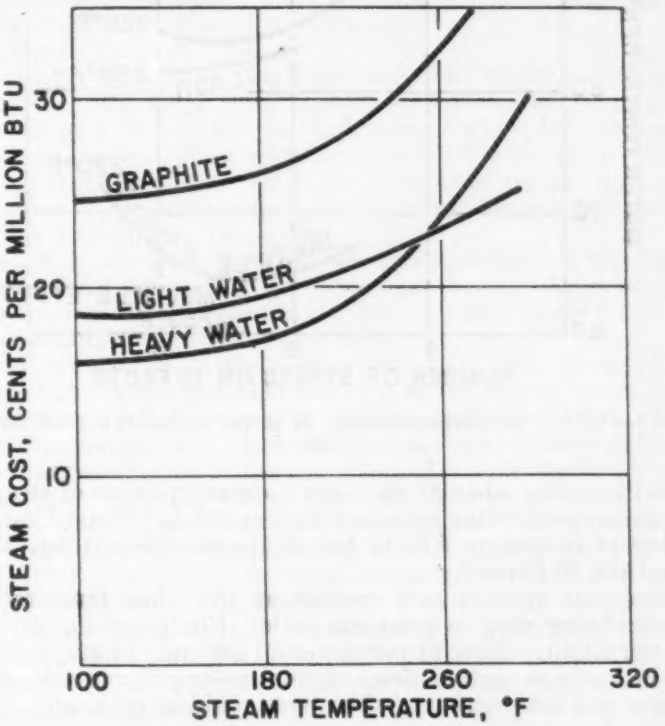


FIGURE 7.—Cost of steam from reactors versus steam temperatures.

This illustrates steam costs, cents per million B. t. u., for three types of reactors that we studied.

Now, we do not mean to imply these are the steam costs of the first reactors. This is the optimum cost after several reactors are in use. Temperature needs would be 180° to 250°. All 3 systems are very close and the cost turned out to be between 20 and 30 cents per million B. t. u. In a place like southern California where oil appears to be going up in cost, something like this might be applicable some day. What can we do with 20 cents per thousand pounds of steam? Next slide, please. (Fig. 8.)

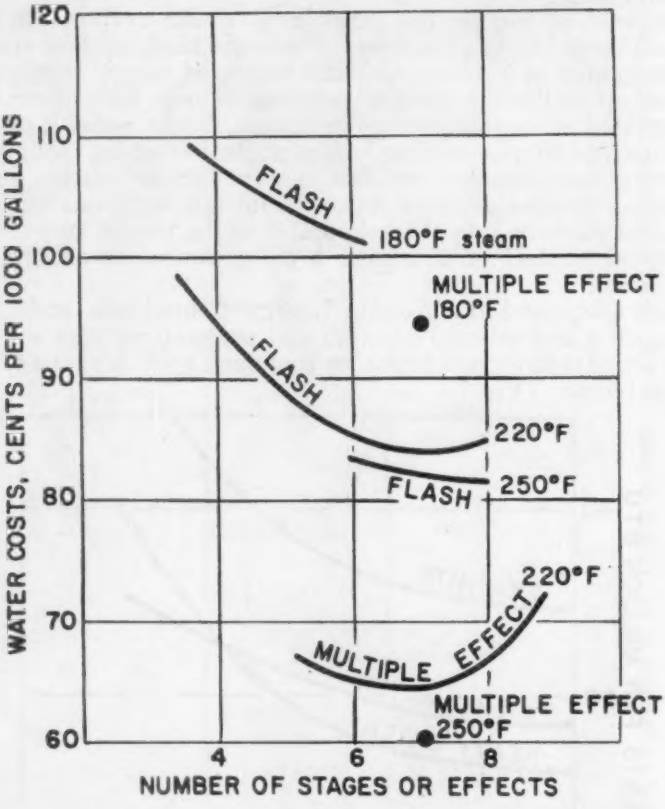


FIGURE 8.—Water costs versus number of stages or effects for minimum steam cost.

This illustrates what 20 cents per thousand pounds of steam might mean in our evaporator systems. It is entitled: "Water Costs Versus Number of Stages or Effects for Minimum Steam Cost, Minimum Steam Cost 20 Cents."

Commercial systems now operate at 180°, low temperature and pressures being used to minimize scale. Flash system, 180°, turned out water slightly above $1 per thousand gallons. If our flash systems could be made to operate more efficiently—in other words, at higher pressures and temperatures—their costs could be reduced.

Now, the Badger system, the long-tube vertical evaporation system, as reestimated by the Fluor Corp., is using 20 cents per thousand gallons of steam, which turns out to be the lowest. This turns out to be 60 cents per thousand gallons for 220° steam.

Before, I mentioned that Mr. Badger said 40 cents per thousand gallons. Actually there is no difference between the two systems except for this, in the Fluor cost estimation, they studied a 10-million-gallon-per day plant; Badger, 17 million gallons per day. Fluor used corrosion-resisting materials; Badger assumed he could get by without it. Fluor charged for chemical treatment for preventing scale, Badger did not.

Now, this 20-cent steam is for a 200-megawatt nuclear reactor. If we build a reactor larger, the cost of the steam might be somewhat reduced.

Flour reestimated for a 400-megawatt reactor and a 50-million-gallon-per-day evaporator plant. The cost turned out to be something close to 50 cents per thousand gallons.

If you use mild steel, as suggested by Mr. Badger, the costs are reduced to less than that.

This completes my short review of our evaporation studies at the present time.

Mr. JONES. Thank you very much.

Mrs. Granahan, do you have any questions?

Mrs. GRANAHAN. No questions.

Mr. JONES. Mr. Indritz?

Mr. INDRITZ. Mr. Cywin, you mentioned costs of 40 cents and 70 cents per thousand gallons. Were those costs arrived at on the basis of the standardized estimating procedure?

Mr. CYWIN. Yes, they were.

Mr. INDRITZ. Now, there was furnished to us by the Assistant Secretary of the Interior a chart, presumably prepared in your office in response to a request by the chairman of the subcommittee, Mr. Jones, as to the actual or estimated costs of converting water at present by those processes which are now more technologically advanced—and that chart appears in the folders of the subcommittee members as item 15, Mrs. Granahan.

The costs which were given to the subcommittee on the basis of the standardized estimating procedure are broken down according to the amount of water produced per day, and they range from—well, some as low as 95 cents and going up to $4.

Now, in what way do the figures that have been given to us in this chart differ from those that you have stated in your presentation?

Mr. CYWIN. Well, I began by talking about the W. L. Badger 17-million-gallon-per-day plant. As I said, the 17-million-gallon-per-day size happened to be at the low point of his economic curve.

If you built a smaller plant, the cost might go up somewhat. If you built a larger plant, you would not gain very much costwise.

So if you look at our submission to the committee, you will see the thermal distillation under development, multiple effect, cost estimate for 10 million gallons per day, 50 cents.

Mr. INDRITZ. Now, what is the largest size plant which has been actually operated to date?

Mr. CYWIN. A 2.5-million-gallon-per-day plant has recently gone into operation at Kuwait.

Mr. INDRITZ. Is that on a multiple-effect distillation?

Mr. CYWIN. That is a multistage flash distillation plant. In addition, there are 2½-million-gallons-per-day capacity of multiple-effect plant, put in some years ago, in operation.

Mr. INDRITZ. Has any officer of Saline Water inspected the plant?

Mr. CYWIN. No one has inspected the plant in Kuwait.

Mr. INDRITZ. On what basis do you make your statement, then, as to cost?

Mr. CYWIN. I did not make a statement as to cost of the Kuwait plant.

Mr. INDRITZ. Do you have the data upon which to make any estimate of cost of the Kuwait plant?

Mr. CYWIN. Well, yesterday we referred to a statement that a representative of Westinghouse presented for the Senator Anderson subcommittee and was in the Anderson hearings.[8] So since we would have to accept their statements as they were presented to us, I would suggest that you accept them as presented in the Anderson hearings.

Mr. INDRITZ. Is there any plan by the Office of Saline Water to check into the cost operating experience of that plant in the near future?

Mr. CYWIN. We—Oh, you mean in Kuwait?

Mr. INDRITZ. Yes.

Mr. CYWIN. We have no immediate plans today to visit the Kuwait plant. However, we have been in conversation and we have visited Westinghouse people, and we have viewed the small pilot plant that they built upon which they based their designs for the Kuwait plant.

Mr. INDRITZ. In connection with distillation processes, is it possible to have a fairly large scale plant that would be used both for production and research purposes at the same time, or are the two purposes exclusive?

Mr. CYWIN. There isn't anything that you do for the first time that you do not learn something from. Or even the second time. In other words, if you built a large plant, you would certainly learn something from it.

Mr. INDRITZ. Even when it is built purely for production?

Mr. CYWIN. You might learn you never should have built it because it doesn't work right.

Mr. INDRITZ. Yes, that is a form of knowledge, too.

You mentioned that the figures you gave were on certain assumptions. For example, there would be no cost or little cost for control of scale.

Mr. CYWIN. That is right.

Mr. INDRITZ. Has that problem been satisfactorily controlled yet?

Mr. CYWIN. The entire reason for our experimenting at Harbor Island is because we do not have a satisfactory solution today. However, our initial results from Harbor Island are very encouraging in this respect.

Mr. INDRITZ. What is the nature of the encouraging results?

Mr. CYWIN. We have operated the equipment, we have operated at scaling temperatures and under scaling conditions, and we have maintained scale-free conditions.

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[8] Hearings before the Subcommittee on Irrigation and Reclamation of the Senate Committee on Interior and Insular Affairs, 85th Cong., 2d sess., on S. J. Res. 135 and S. 3370, March 20 and 21, 1958, pp. 127 ff.

Mr. INDRITZ. At low or little cost?

Mr. CYWIN. What would be low or little cost in major plants. This is all experimental work. It has to be verified. We have to test these things under more severe conditions.

Mr. INDRITZ. There was an article in the New York Times of March 7, 1958, concerning a so-called multiple-effect centrifugal evaporator produced by a Dr. Louis Bromley, of the University of California, in which he estimates production of water at a cost of from 25 to 50 cents per thousand gallons.

Could you tell us a little about that?

Mr. CYWIN. Well, I can tell you what I know about it. We have corresponded with the University of California and with Dr. Bromley to some extent.

The centrifugal still that he has conceived is an adaptation of the Hickman still which we are working on. He has conceived it as a multiple-effect system. We for some time also thought of developing a multiple effect Hickman still. However, Dr. Hickman has convinced us that a compression system has more advantages at the present time.

Dr. Bromley, from newspaper accounts, has stated that it is going to take him 5 or 6 years to develop his equipment also, and so his estimates are really preliminary estimates. We also do not know what his estimates were based on since we do not have a copy of the estimates.

Mr. INDRITZ. You have not conferred with him yet, have you?

Mr. CYWIN. We have conferred with Professor Howe, who is in charge of the sea water conversion program out there, and he has not given us any statistics as to how the estimates were arrived at.

Mr. INDRITZ. Have you any suggestions to the committee as to how Congress might, either by legislation or by appropriation, or by a supplemental appropriation, aid the distillation processes?

Mr. CYWIN. Well, you mean aid the projects that I spoke about?

Mr. INDRITZ. The whole program on distillation.

Mr. CYWIN. We have certain projects that we have justified and which we are asking money for. If Congress will give us the money for those projects, we certainly will be able to make the progress we would like to.

Mr. INDRITZ. Would that cover all of the projects which are now in ready stage for pilot-plant work? Or just some of them?

Mr. CYWIN. Well, those projects which are approaching pilot-plant work, only 2 or 3 are being funded for in our estimates for the next year.

Mr. JONES. Mr. Cywin, do you think $25,000 out of $725,000 expended in 1958 for basic research is a sufficient amount or apportionment of moneys for that purpose?

Mr. CYWIN. Congressman Jones, you cannot spend enough for research and development if you want to learn things.

Mr. JONES. Yes, sir.

Mr. CYWIN. Learn, get ideas, gain knowledge.

Mr. JONES. Yes, sir.

Mr. CYWIN. However, our laws specifically state we are to direct our research toward saline water conversion. Thus we are really limited in the types of basic research we might sponsor.

Mr. JONES. All right, now you are getting down to what we are having this meeting for. Please tell us which limitations imposed on you should be modified or removed so we can get a larger percentage of your money directed toward the basic research.

Mr. CYWIN. Well——

Mr. JONES. We want to help you whether you want to be helped or not.

Mr. CYWIN. I said limited. I did not mean limited by money so much as limited by area of technical knowledge.

National Science Foundation, for example, as I understand their charter, can let contracts or grants for studies that might gain knowledge; no one knows for sure that this knowledge can be applied to a specific purpose. However, when we let a contract for a basic research study, we have to have some indication that this knowledge might be applied specifically to saline water conversion process cost reduction.

Mr. JONES. Now, Mr. Jenkins testified yesterday he got acquainted with a man up at New York University and paid him $4,000 just to sit down and think. That proved to be a very valuable and wise investment because as a result of that, you are now carrying out a research contract on what he was able to "think." Now, let's see if we cannot find some other people to sit down and think. So can we spend a little more money for more thinking?

Mr. CYWIN. Congressman Jones, that is exactly what we are trying to do. For example, in the W. L. Badger project I mentioned first——

Mr. JONES. Now, you people are the ones to convince me. I am not trying to convince you. I am taking just what you all said. I find no difference between Dr. Bronk, Dr. Waterman, and Dr. Killian; and then I find Mr. Jenkins, Dr. Schroeder, Dr. Gillam—all of them are of the same opinion.

Now, if we are all in accord as to the type of program we want, why is it that only $25,000 is spent for basic research out of $800,000?

Mr. CYWIN. Well, I would just like to review some of our idea generating for you, Congressman Jones.

Our original contract with W. L. Badger was for cost estimating optimum cycles. As a result of that little contract, Mr. Badger has conceived a new method for preventing scale in our evaporation systems. This is the type of stimulation that we have been seeking out and trying to achieve, and I do not for a minute disagree with that battery of eminent people you mentioned before.

Mr. JONES. Well, you know I am a lawyer, and I like to try to get the best evidence to go to court with, and it seems to me there is pretty good evidence from your testimony, and from all the others with whom I have associated you, that there is no disagreement as to how to go about these research programs.

I see nothing too different with your program and the others that they have described or been associated with.

Thank you very much, Mr. Cywin.

Mr. CYWIN. Thank you, sir.

Mr. JONES. Our next witness is Dr. Luna B. Leopold, Chief Hydraulic Engineer, Geological Survey.

We are glad to have you, Dr. Leopold.

Dr. LEOPOLD. Thank you, Mr. Chairman.

## STATEMENT OF DR. LUNA B. LEOPOLD, CHIEF HYDRAULIC ENGINEER, GEOLOGICAL SURVEY

Dr. LEOPOLD. When you wrote to the Secretary of Interior on April 1, you asked if the Geological Survey would present a brief statement to the committee concerning two items. The first is the occurrence of saline water in places where there is a present or potential water shortage; and secondly, some information on water costs that apply to water delivered at the tap.

It is rather difficult to provide an adequate statement upon the first request because we could go into considerable detail. So with your permission, I would like to read a very brief statement which summarizes the material which is included in a more comprehensive statement, the latter to be included in the record if you see fit.

If I may proceed with reading this very brief statement, Mr. Chairman?

Mr. JONES. Yes, sir, you go right ahead, Dr. Leopold.

Dr. LEOPOLD. In 1955, the water withdrawn from streams, reservoirs, and wells in the United States for all principal uses amounted to 240 billion gallons per day, and this amounts to 1,500 gallons per capita per day. A little less than half of this was withdrawn by industries directly for their own use, and approximately an equal amount was diverted for irrigation. Of the total water which was withdrawn for all uses, about a fourth was consumed rather than returned to surface streams and was therefore lost to further reuse.

In the Eastern United States, industrial uses are more important than any other. In the western part of the country, irrigation is the principal use of water. Though essentially no saline water is used for irrigation, about 19 billion gallons per day of saline water was utilized in industry, or about 17 percent of the total water used by industry. These figures show that there are some purposes, though restricted, for which saline water can be used in industry. Among such purposes cooling is an important one and the main restriction to the use of saline waters for cooling purposes is the corrosion of distribution pipes and other facilities.

Now with regard to future water use, it is estimated by various persons who have studied the problem that by 1980, the daily water use in the United States will increase from its present value of 240 to between 400 and 600 billion gallons per day. Estimates of future water use are usually based on the present, taking into account trends in the growth of population and industry, in per capita use and in other factors. Most forecasts make no allowance for increased economy or efficiency in the use of water. Therefore, to the extent that economy and efficiency in water use improve, the estimates will be in error.

No sound estimate is available on the potential increased use of untreated saline waters for industrial purposes. In the absence of such figures, one might suppose that the present figure, 17 percent, will continue to be a reasonable expression fo the future percentage of total industrial use in which saline waters can be employed.

Areas which are already short of water, or seem likely to be short within a decade or two, can be delineated, at least in general terms, and present information allows a reasonable estimate of whether

saline waters are available in those areas. However, a detailed review of the condition in such water-short areas is not practicable in this brief statement. Outstanding examples of presently or potentially water-short areas could be included in the following general categories.

I have listed here under Eastern United States, Delaware and Hudson River drainage areas and Chesapeake Bay area, and portions of Georgia and Florida. Under the Great Plains area, Kansas and Oklahoma. Also, parts of Arkansas-White-Red River Basins, High Plains in parts of Texas, Oklahoma, and New Mexico——

Mr. JONES. Off the record.

(Discussion off the record.)

Dr. LEOPOLD. In the western Gulf of Mexico Basin, portions of Pecos and Rio Grande Basins and portions of central Texas should be included; and what might be included in the western mountain area, portions of Colorado River Basin, great basin, and California coastal area.

Mr. JONES. Off the record.

(Discussion off the record.)

Mr. JONES. You go right ahead, sir.

Dr. LEOPOLD. For each of the areas mentioned, the Geological Survey has prepared a brief statement mentioning the nature and degree of present water shortage and some facts concerning the availability of saline waters which might be used in the future, either directly for some industrial purposes, or for conversion. The information, which is broken down area by area, may be summarized by saying that in all areas where water is either presently short or potentially short within a decade or two, some saline water is available and the amounts of such saline waters are locally considerable.

Now with regard to water costs, the Geological Survey does not ordinarily collect data on the cost of construction and operation of water-supply facilities in the course of its normal investigations of the water resources. However, technical journals and other sources contain considerable information on such costs.

The costs of water-supply facilities are the result of several factors, the most important of which is the relative accessibility of the source. In viewing costs of water delivered at the tap, several things must be kept in mind. Construction costs have increased about sevenfold during the 44-year period from 1913 to 1957. Present water charges to the ultimate consumer supplied by public systems may not reflect realistically the development costs. For example, in long-established communities, the cost of dams and reservoirs from which the current supply is obtained may have been completely amortized and water rates may represent only current operating costs. In other instances, a portion of the works may have been financed by tax levies——

Mr. JONES. Do not go too fast for us, Doctor, because this is a very important statement, and one of considerable interest to me.

Dr. LEOPOLD. Let me go back and say in other instances, a portion of the works may have been financed by tax levies and such portion might not be completely reflected in the customer rates. Ordinarily, however, a water system has been developed progressively with the growth of need, and water rates are based on amortization charges for different engineering facilities constructed on different dates, plus current operation costs.

I summarize now some cost surveys published in technical journals. Interpretation of these examples should bear in mind the qualifications just mentioned.

One survey shows that costs for small quantities of city water delivered at the tap vary from about $90 to $1,000 per million gallons, with a median value of $350.

To help you, Mr. Chairman, at the end of my statement is a little conversion table; since everyone is speaking of different units, it is hard to know what units the individual listeners find it easier to understand.

Mr. JONES. Yes.

Dr. LEOPOLD. It should be understood, however, that the rates are considerably lower for large consumers; and further, that costs of water at the treatment plant are much less than water delivered at the tap, because the distribution system is an important part of the total cost to the ultimate consumer.

Assuming a relatively large demand, about 14 million gallons per day, 1 published survey shows that to supply new water facilities under 1957 price levels would cost from $38 to $400 per million gallons.

Mr. JONES. Interest rates have gone up.

Dr. LEOPOLD. Well, cost of construction has gone up.

Mr. JONES. Interest rates, too.

Dr. LEOPOLD. Industrial water costs are even more variable, primarily because of the different quality requirements for water used for different purposes. A study disclosed that in 1942, industrial water delivered at the place of use ranged in cost from 60 cents to $50 per million gallons, with a median cost of $8 per million gallons. It might be reasonable to assume that costs would be about 3 to 4 times as great today.

Current costs of irrigation water to the water user have been computed by the Bureau of Reclamation. The estimated charges per acre-foot to the water user vary approximately—and you will see we are jumping now to irrigation units——

Mr. JONES. Yes.

Dr. LEOPOLD. Between $1.65 and $42 per acre-foot, with a median value of about $4.50 per acre-foot.

Mr. JONES. Let's stop there—off the record.

(Discussion off the record.)

Dr. LEOPOLD. In viewing these figures, I might note it takes about 3 acre-feet to make a million gallons.

That completes my oral statement, Mr. Chairman.

Each of these items is covered in a little bit more detail in the attached pages, which I would like to submit for the record.

Mr. JONES. Without objection, that will be part of the record.

(The document referred to is as follows:)

FURTHER INFORMATION ON SALINE WATER IN WATER-DEFICIENT AREAS, AND ON COSTS, BY DR. LEOPOLD OF THE UNITED STATES GEOLOGICAL SURVEY

EASTERN UNITED STATES, GENERAL

In the East, saline surface water occurs chiefly in tidal streams, estuaries, and bays. The concentration of dissolved salts at any given place depends on the fresh-water discharge of streams and on the tidal stage.

Despite the fact that the Atlantic and Gulf Coastal Plain as a whole has the greatest reserve of fresh ground water in the entire country, as a region it can

be classified with other areas of current or potential shortage because so many local areas are experiencing, or some will experience, water shortage. These local shortages are due to overdevelopment in relation to the water supply, which locally is anything but abundant.

As to availability of saline water, slightly to moderately saline ground water is available in moderate to large quantities from shallow to deep formations at many places. A narrow belt along the coast from New England to Texas, almost the entire States of Louisiana and Florida, and large parts of Alabama, Mississippi, Arkansas, and Texas have large quantities of saline water at moderate depths below fresh ground water.

The following paragraphs discuss in somewhat more detail some of the specific areas of shortage.

*Delaware River and Hudson River Basins.*—This region is humid and well watered, but water demands are very large, and dependable local supplies of water for new municipal supplies and industry are becoming increasingly expensive to obtain or develop. New York City has developed sources as far away as the headwaters of the Delaware River. Tidal reaches of the Hudson and Delaware Rivers have been penetrated by salt water. The Hudson River is affected by sea water as far upstream as Poughkeepsie, N. Y., and saline water having a chloride content of 1,000 parts per million has been observed even as far upstream as West Point.

In the Philadelphia-Camden area, the Delaware River is the principal source of water for many industries and municipal supplies. Both industries and municipalities use it for disposal of their wastes. Ground-water sources adjacent to the river receive some recharge of poor quality water from it. Deepening of the ship channel here, which has been proposed, would increase the interchange of water between the stream and the aquifer.

The depth at which saline water occurs along the Atlantic coast varies widely. Sea water encroachment into aquifers has occurred in many heavily pumped areas along the coast and is impending in many others. Many wells ranging in depth from 250 to 1,000 feet immediately adjacent to the coasts of New Jersey and Delaware yield saline water. The yields of these wells range from a few gallons per minute to more than 1,200 gallons per minute. In the lower Delaware River area in New Jersey, because of heavy industrial pumping, some of the deeper water-bearing formations yield salty water.

### SOUTHEASTERN UNITED STATES

At Savannah, Ga., heavy pumping of ground water for municipalities and industry has developed a cone of depression that extends outward more than 20 miles. Near the center of the cone ground-water levels have declined as much as 100 feet. Salty water has not yet appeared in the wells but may be moving slowly inland toward them from areas some miles away. Deep aquifers which yield saline water are rarely pumped.

The highly permeable aquifers in the coastal areas of Florida, especially near Miami, are subject to salt-water encroachment from the ocean. Most, if not all, of the State of Florida is underlain by formations that contain saline water.

Throughout much of Florida's coastal area, conditions permit salt-water contamination of ground water in the coastal lowlands. Most of the aquifers communicate directly with the sea, and salt water has moved into aquifers tapped by wells in many municipal water-supply systems. In some cases new well fields or other sources of supply have been necessary. The principal artesian aquifer in Florida is the source of water for thousands of wells and the largest limestone springs in the world. It contains water high in chloride throughout a broad coastal belt extending around the peninsula.

*The Great Plains area—General.*—In the semiarid section of the Missouri River Basin many rivers and streams are saline at low flows. The salinity commonly increases downstream owing to pickup of natural salt and the entry of return flows from irrigated land. This water is used for stock but rarely for irrigation. It is unsuitable for domestic supplies.

Fresh ground-water supplied are generally deficient except in areas underlain by geologically young deposits of sand and gravel. The most extensive aquifers pumped for domestic, municipal, and irrigation use in places yield slightly to highly saline water.

*Kansas.*—Saline surface waters are one of the major problems in Kansas. The principal source of this water is a north-south band about 150 miles wide across the central part of the State. In this band salt-bearing rocks occur from the southern border of the State northward almost to the valley of the South Fork of the Solomon River and eastward to the confluence of the Saline and Smoky Hill Rivers. In places the value base flow of the streams constitutes as much as 35 percent of the total flow.

In Kansas, as in most of the Great Plains, the Dakota sandstone is one of the most extensive aquifers and an important source of artesian water. Ground water from the formation is used extensively for domestic, stock, and irrigation purposes despite dissolved materials amounting to 1,000 parts per million in shallow wells and 5,000 parts per million at depths of 1,000 to 2,000 feet. Yields of wells tapping the Dakota sandstone range from only a few gallons to several hundred gallons per minute, but the aquifer has a low rate of recharge.

*Arkansas-White-Red River Basin.*—Wide seasonal and yearly variations in the surface-water supply are characteristic of this region. Without reservoir storage of surface water, only a nominal percentage of the gross supply would be available for use. Much of the water that is fully developed in the eastern parts of the area in Kansas, Oklahoma, and Texas is saline. Cities in the headwaters of the basins, such as La Junta, Las Animas, Rocky Ford, and Lamar, Colo., have serious water shortages during droughts.

Water in the Arkansas River is saline most of the time from John Martin Reservoir, Colo., to Muskogee, Okla. The river enters an area of salt rocks near Hutchinson, Kans., and drainage from salt marshes and industrial wastes from saltworks increase the salinity of the water. Dissolved solids average about 1,700 parts per million, but at times the concentration is more than 5,000 parts per million.

Water is diverted from the North Canadian River at Oklahoma City to Lakes Overholzer and Hefner for municipal water supply. Downstream from the point of diversion the stream is polluted by oilfield brines and is too saline for general use. The Canadian River crosses salt beds in western Oklahoma, and a chloride content of nearly 5,000 parts per million has been measured even at moderately high discharges.

In 1953 the Canadian River near Whitefield, Okla., was saline, on the average, 5 days out of 6, and the total flow on those days represented 11 percent of the annual streamflow.

Principal cities in western Oklahoma and parts of Kansas are perennially short of municipal and industrial water because the natural supply is small and either naturally saline or polluted by industrial wastes. The explosive growth of Oklahoma City since 1945 resulted in a serious water shortage during the drought of 1950–57. The shortage was temporarily alleviated by drilling about 70 wells in a shallow aquifer and 17 wells in a deeper sandstone aquifer. The shallow wells have a productive life expectancy of only 90 days.

The Ogallala formation is by far the most important aquifer in the High Plains of northern Texas, western Oklahoma, Kansas, and Nebraska, and eastern New Mexico, where it is the major source of water supplies for all use. Yields of several hundred gallons per minute are obtained from sands and gravel at shallow to moderate depths and yields of 1,500 gallons per minute are not uncommon. Analyses indicate a mineral content in some localities as much as 2,000 parts per million. Locally the water has become more saline owing to heavy pumping and consequent encroachment of saline water from the underlying older rocks.

In east-central New Mexico large quantities of moderately saline ground water are available from formations other than the Ogallala. Permian limestone supplies large amounts for irrigation in the Roswell artesian basin of southeastern New Mexico. Ground water containing as much as 4,000 parts per million of dissolved solids is used extensively for irrigation in much of the area.

### WESTERN GULF AREA

The balance between supply and demand is favorable in the more humid eastern part of the area but demand is approaching dependable supply in the western part. The two principal farming areas, the Rio Grande Valley and the Pecos River Valley, definitely are short of water for irrigation. Many parts of Texas are deficient of irrigation water, and in the northwestern part (High

Plains) part of the State pumping from wells is depleting the supply much faster than it is being replenished.

Pumpage of ground water for irrigation in the High Plains of Texas increased from very little in 1935, when the present irrigation economy can be said to have begun, to 1,175,000 acre-feet in 1949 and about 5 million in 1954. Recharge is estimated to be about 50,000 acre-feet per year, so that currently the ratio of pumpage to recharge is about 100 to 1.

From Roswell, N. Mex., south to the Red Bluff Reservoir in Texas, salinity of the Pecos River is increased by inflow from brine springs in the Malaga Bend area above Red Bluff Reservoir. The brine inflow, averaging about 430 tons of salt per day, adversely affects the quality of the river water to the extent that it can be used for irrigation only by special land practices involving the use of large quantities of water to leach the soil. The salinity of the Pecos River ranges from about 1,500 parts per million at Puerto de Luna, N. Mex, to more than 10,000 parts per million at times near Grand Falls, Tex.

Many cities in north-central and south-central Texas are supplied with slightly saline water from aquifers at moderate depths. Some flowing wells yield more than 500 gallons per minute. A well owned by the city of Dallas, 819 feet deep, yielded 250 gallons per minute of water having a dissolved-solids content of 3,380 parts per million.

### WESTERN MOUNTAIN REGION

In most of the streams in the Colorado River Basin, storage is a prerequisite for development. Water is saline principally at low flow. At Littlefield, Ariz., near the mouth of the Virgin River, mineral springs contribute an average of about 38.8 million gallons a day which constitutes most of the low flow of the stream. The slightly saline waters of the basin are used for irrigation but are not suitable for domestic use.

Low flows of the Gila River at Gillespie Dam, Ariz., carry more than 6,000 parts per million of dissolved solids; flood flows are comparatively dilute, but in the recent drought years they have not contributed much water.

Saline ground water is used extensively for irrigation in southern Arizona and southern New Mexico. Saline water is available in large quantities from alluvium along streams and deeper alluvium in parts of many basins. Only small yields of saline water may be expected from the central areas of closed basins.

The Coconino sandstone is the chief deep water-bearing source in Arizona, yielding several hundred gallons per minute to wells in some localities. The water becomes increasingly highly mineralized with depth.

In the Great Basin the salinity of the lake waters varies with the amount of fresh-water inflow. The current estimate of volume of water in the Salton Sea (dissolved solids, 38,000 parts per million in 1951) is 5 million acre-feet Most of the water that drains to the sea is irrigation return flow.

According to present estimates, demand in the Colorado River and Great Basin will equal supply in about 25 years, and poor quality of water may be a limiting factor in some localities. Although the current supply and demand are not far out of balance, much more water could be used for irrigation if it were available.

In nearly all of Arizona, municipal and industrial water is in short supply during droughts. Water in the southern third of the State is inadequate to meet all irrigation needs. Many towns had water shortages during the recent drought of 1954–57.

*California coastal area.*—Here the balance between supply and demand is favorable if the area as a whole is considered, there being a surplus in the northern part and a shortage in the southern part.

In the Long Beach, Santa Ana, Huntington Beach, and Orange County areas, salt water has invaded the shallow aquifers. Very saline waters occur in deep aquifers in the area.

In the Central Valley, which consists of the Sacramento and San Joaquin River Valleys, saline water occurs in a wide belt extending from south of Bakersfield to the delta region near Stockton. In the Sacramento Valley it occurs at shallow depths in a small area in Sutter County. In both areas water containing 2,000 to 3,000 parts per million of dissolved solids is obtained from wells

yielding as much as 1,500 gallons per minute. The water is used extensively for irrigation.

In other, smaller coastal areas where ground-water withdrawal by pumping is extensive, encroachment of sea water or salty water from deeper formations has occurred.

### SOME DATA ON COST OF WATER DELIVERED AT THE TAP

The Geological Survey does not ordinarily collect data on the cost of construction and operation of water-supply facilities in the course of its water investigations. Technical journals, however, contain information on the costs of construction of wells, structures for impoundment, and delivery systems. Also, municipal water rates and other charges for water are often published. Some of these data are summarized below.

The costs of water-supply facilities are the result of several factors, the most important of which is the relative accessibility of the source. A city fortunate enough to be able to draw its water from a nearby river without impoundment and with little treatment may be able to meet its needs at relatively little cost, even in an arid area. Accessibility, however, is not necessarily related to adequacy of the supply. In the relatively humid Eastern United States it may be necessary for a city to seek relatively distant sources for an adequate supply.

Furthermore, low-cost supplies are developed first and later expansion may result in much greater cost. Additional supplies in well-developed areas often cost considerably more than earlier supplies. Costs are affected also by the inflationary trend. Construction costs have increased about sevenfold during the 44-year period from 1913 to 1957. Values for selected years follow:

| Year: | *Engineering News-Record construction cost index* |
|---|---|
| 1913 | 100 |
| 1920 | 251 |
| 1930 | 203 |
| 1932 | 157 |
| 1940 | 242 |
| 1945 | 308 |
| 1952 | 569 |
| 1957 | 720 |

From this table it may be seen that capital costs of 25 years ago were only about a fifth of what they are today. Even if amortization costs are included, they would vary greatly dependent on date of construction of the principal works.

Water charges to the ultimate consumer at the tap or headgate, especially for public systems, may not reflect realistically the development costs. For example, in long-established communities the costs of dams and reservoirs from which the current water supply is obtained may have been completely amortized and water rates may represent only current operating costs. In other instances a portion of the works is financed by tax levies and not completely reflected in customer rates. On the other hand, some water is sold by organizations that charge rates as high as the public utility commissions will permit and may be as high as the user will pay. Ordinarily, however, a water system has been developed along with the city or irrigation district that it supplies and water rates are based on amortization charges for several reservoirs, well systems, pipelines, or treatment plants at different dates, plus current operation costs.

The Journal of the American Water Works Association for May 1957 contains (on pp. 616–641) the 1955 monthly rates per 1,000 cubic feet for 480 cities in the United States having a combined population of 70 million, more than 60 percent of the population served by water utilities. Costs ranged from $0.68 to $7.50 for the first 1,000 cubic feet used in a given month, with a median value of $2.60.

Water rates in some sample cities are included in the following table:

| City | Cost to consumer for water delivered at tap, in dollars (1955) | |
|---|---|---|
| | For 1st 1,000 cubic feet used in a given month | For 1st 100,000 cubic feet used in a given month |
| Akron, Ohio | 1.97 | 148.73 |
| Albany, N. Y | 1.80 | 180.00 |
| Albuquerque, N. Mex | 2.15 | 135.29 |
| Amarillo, Tex | 2.00 | 166.50 |
| Atlanta, Ga | 1.91 | 187.97 |
| Bangor, Maine | 1.00 | 35.66 |
| Bismarck, N. Dak | 4.95 | 245.73 |
| Boulder, Colo | 1.87 | 113.75 |
| Burbank, Calif | 1.75 | 117.30 |
| Burlington, N. C | 3.53 | 193.15 |
| Butte, Mont | 2.90 | 125.00 |
| Chicago, Ill | .90 | 90.00 |
| Clinton, Iowa | 4.88 | 186.60 |
| Dallas, Tex | 2.78 | 146.55 |
| Denver, Colo | 1.97 | 118.71 |
| Dodge City, Kans | 3.55 | 116.30 |
| Eugene, Oreg | 1.99 | 72.94 |
| Fort Wayne, Ind | 2.45 | 124.05 |
| Lincoln, Nebr | 1.68 | 83.85 |
| Los Angeles, Calif | 2.08 | 122.77 |
| Memphis, Tenn | 3.00 | 152.70 |
| Miami, Fla | 2.05 | 120.90 |
| Nashville, Tenn | 2.40 | 143.40 |
| New York, N. Y | 1.50 | 150.00 |
| Pasadena, Calif | 2.25 | 135.00 |
| Phoenix, Ariz | 2.00 | 136.60 |
| St. Louis, Mo | 1.45 | 80.65 |
| Seattle, Wash | 1.70 | 170.70 |
| Shelbyville, Ind | 3.05 | 118.25 |
| Sheridan, Wyo | 1.47 | 43.59 |
| Spokane, Wash | .93 | 89.96 |
| Tacoma, Wash | 1.30 | 69.75 |
| Tucson, Ariz | 2.07 | 102.06 |
| Tulsa, Okla | 4.18 | 141.35 |
| Washington, D. C | 1.44 | 110.34 |

Industrial water costs are even more variable, primarily because of the different quality requirements for water used for different purposes. A sample of the results of a survey of water costs in the pulp and paper industry was published in Monograph No. 1 of the Technical Association of the Pulp and Paper Industry in 1942. Costs per million gallons were reported from 37 plants. Costs ranged from $0.60 to $50 or more per million gallons, with a median of $8 per million gallons. On the basis of the Engineering News-Record's cost index it might be reasonable to assume that costs would be about three times as great today.

The Engineering News-Record for February 26, 1953, reports briefly on water costs for water supplies for 233 general areas in the United States and Alaska based on 1952 construction costs. The survey was made for the Bureau of Mines under a contract with the Corps of Engineers, by Ford, Bacon & Davis, Inc., of New York, assisted by a group of consultants. Malcolm Pirnie Engineers, New York, conducted the water-supply investigations. In each case costs of a new water supply furnishing 13 to 14 million gallons per day was estimated. Water costs were estimated to range between about $30 and $315 per million gallons. If the Engineering News-Record cost index were applied to obtain 1957 costs, they would range from $38 to $400 per million gallons, or 4 to 40 cents per thousand gallons.

Some estimates of current costs of irrigation water to the user have been computed by the Bureau of Reclamation. The estimated charges per acre-foot to the water user for 23 projects vary between $1.65 and $42 per acre-foot, the median value being about $4.50 per acre-foot. Most of the 23 projects are under construction by the Bureau of Reclamation, but some recently completed projects and some being proposed for early construction are also included. This is indicative of the range in charges on all Bureau projects providing both a full and a

supplemental supply. The estimated charges also give an indication of the wide variations in irrigation water charges, as well as some indication of the value of water used for irrigation.

Data on municipal, industrial, and agricultural water have been reported in the units generally used in those fields. For convenience in conversion to common units the following comparisons are given:

1,000 cubic feet=7,480 gallons.
1 acre-foot=326,000 gallons.
1.53 cubic feet per second=1 million gallons per day=approximately 3 acre-feet per day.

Dr. LEOPOLD. On page 7, toward the end of my supplemental statement, you will notice, under the heading "Cost to Consumer for Water Delivered at Tap, in Dollars (1955)," two columns applying to quite a number of cities. The costs listed are in the left column for the first thousand cubic feet used in a given month; the right column for the first 100,000 cubic feet used in the first month. You can see the number of cubic feet has been increased by 100 and the cost obviously goes down per unit with increased delivery rate.

Let's take the first example to make this clear. At Akron, Ohio, the first thousand cubic feet would cost $1.97; but if you take the next column, $148, and divide it by 100, if you were buying it at large quantities, instead of paying $1.97 you would only pay $1.48.

Mr. JONES. Yes.

Dr. LEOPOLD. The cost is going down with increasing amounts delivered.

Now, for your further information, may I point out that we have recently completed studies in the Geological Survey of the very item No. 1 which you have asked for. This study is Geological Survey Water Supply Paper 1374, published in 1957, and is entitled "Preliminary Survey of the Saline Water Resources of the United States." It is a reconnaissance survey, but here is a whole book, actually, you might say, dealing with part 1 of your question. So that actually this is still a greater amplification of the statement which I have presented to you here.

There is also another——

Mr. JONES. Staff will make a note to get a copy of that to each member, because I know that would be of great interest.

Dr. LEOPOLD. This, by the way, was just published in 1957. It is relatively new.

We are also making studies of saline water resources of individual States. Here is one for the State of Texas only a year or so old. It is Geological Survey Water Supply Paper 1365 published in 1956, entitled "Saline-Water Resources of Texas."

I would like to point out, in addition, that these studies of the occurrence of saline water in the United States, and in particularly important geographic areas, are a normal important part of the water resources investigation made by the Geological Survey and were not made necessarily in connection with the saline water conversion program.

We believe the conversion of saline water is of sufficient importance throughout the United States to justify a study of saline water resources as well as fresh water resources in connection with our regular water resources investigations.

In case any of the members are not acquainted with the other types of material on water quality which are put out by the Geological Survey, here is a sample of a yearly publication, which is the regular type of work that we do on water quality. This is not only a textual discussion, but contains tabular data on the occurrence of water of different quality throughout the United States. This one is Geological Survey Water Supply Paper 1290, published in 1957, entitled "Quality of Surface Waters of the United States, 1953" with subtitle "Parts 1–4, North Atlantic Slope Basins to St. Lawrence River Basin." This, of course, is part of a set.

Mr. JONES. Would you be kind enough to send to the subcommittee about 15 copies of each of those?

Dr. LEOPOLD. I would be very glad to, Mr. Chairman.

Mr. JONES. So we could distribute them among the members.

Dr. LEOPOLD. Be very glad to.

Mr. JONES. Because I know they will be of interest.

Mrs. Granahan, do you have any questions?

Mrs. GRANAHAN. No, sir; I have not.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. Dr. Leopold, has there been any study by the Geological Survey, subsequent to 1955, to bring up to date the Geological Survey Circular 398, entitled "Estimated Use of Water in the United States, 1955"?

Dr. LEOPOLD. No, sir. That is a relatively recent publication.

As you can imagine, it takes quite a long time for the consummation and publication of a study of this sort, and so the reason that 1955 is listed is that we were studying 1955 figures. It was published I think last year. The lag only represents the amount of time necessary to make the study.

However, in answer to your question, continued study of water use is proceeding in the Water Resources Division and those figures are currently being kept up to date insofar as possible when they become available.

Mr. INDRITZ. Could you also provide the committee with 15 copies of that publication, Geological Survey Circular 398?

Dr. LEOPOLD. I will be delighted to, yes.

Mr. INDRITZ. Dr. Leopold, are you familiar with a study entitled "Availability of Water in the United States with Special Reference to Industrial Needs by 1980," issued apparently by the Industrial College of the Armed Forces and authored by Mr. D. R. Woodward, of the Office of the Director of the Geological Survey?

Dr. LEOPOLD. Yes, sir. Mr. Woodward actually was on leave—yes, I am acquainted with it, sir, thank you—Mr. Woodward was on leave from the Geological Survey at the time that he made that study and because it was actually, as I understand it, a thesis of this study group, it was published in that format.

It was not made under the auspices of the Survey, but he is an experienced engineer in the field and I think that it is a sound study, although I am not sure that it would have come to exactly the same conclusions had it been made by the Survey and reviewed under our auspices. However, this is a very sound study by an experienced man as I say.

Mr. INDRITZ. Do you think that the information which is contained in the several circulars and pamphlets you have just mentioned would be of great aid to companies and industries interested in the problem of saline water conversion and in their understanding of what water resources are available in the areas where water is short and where saline water could be utilized, and that it may aid them in understanding better the problems that they have to deal with?

Dr. LEOPOLD. Yes. One would hope actually that the type of work which is done by a scientific organization, such as the Geological Survey, would become better known among the people in the water-resource field.

Understand, though, that there is a problem of getting such published information around. As is the case of many Government documents, these reports are usually purchased from the Superintendent of Documents, and so very often it is a matter of somebody hearing about the fact that such data are available.

The people, who, however, are working in the field of water supply I think are quite well aware of the kinds of information which the Survey puts out. And as a matter of fact, some of the material is used by consulting engineers and other people in the water-supply field long before it is published, practically as soon as it comes off of the recorder charts. So that the people who need it most do obtain it and obtain it immediately from our district engineers in the field.

I suppose there are industrial plants and other people in commercial fields, who do not deal with this as a matter of course, who probably are not acquainted with the work done by the Geological Survey in the water field.

Mr. INDRITZ. Among the numerous letters that the committee has received from people interested in saline water conversion, there have been a number of instances in which it has been stated that they would certainly welcome more knowledge as to the available water sources in the arid sections of the United States. You indicate that these pamphlets supply that. I assume, Dr. Leopold, that all of these documents are available to the public? Are they restricted in any way?

Dr. LEOPOLD. No. As a matter of fact, that is the reason they are published. They are for the use of the public, and that is the reason they are sold by the Superintendent of Documents.

As you know, much of the material of a technical nature which is for sale by the Superintendent of Documents takes a long time to come to the attention of people who might be interested. I think that this is a general problem since there are——

Mr. JONES. Off the record.

(Discussion off the record.)

Mr. INDRITZ. Dr. Leopold, could you give us some instances of typical industrial water uses, and particularly the large quantities of water that are necessary per ton of industrial product?

Dr. LEOPOLD. As a matter of fact, we have special studies going on in the Water Resources Division of water use by individual industries, and there is published by the Geological Survey in that same format studies of several industries.

There is a study of the paper and pulp industry, the carbon black industry; we are now making a study of the water used by the steel industry——

Mr. INDRITZ. How much water is used, for example, to produce a ton of steel?

Dr. LEOPOLD. Well, you handed me the Woodward report, and his data actually come from the Geological Survey data. I do not remember these figures, but I would quote, with your permission, what he stated from the Survey data.

The Geological Survey states that it takes about 65,000 gallons to produce a ton of steel; to make paper from wood, 38,000 to 184,000 gallons per ton—that is a lot of water; synthetic rubber is listed here as 660,000 gallons per ton.

It should be remembered in the field of water use that part of the use is concerned with the process, part with cooling. In other words, this is not water that goes into the product but is used in the industry.

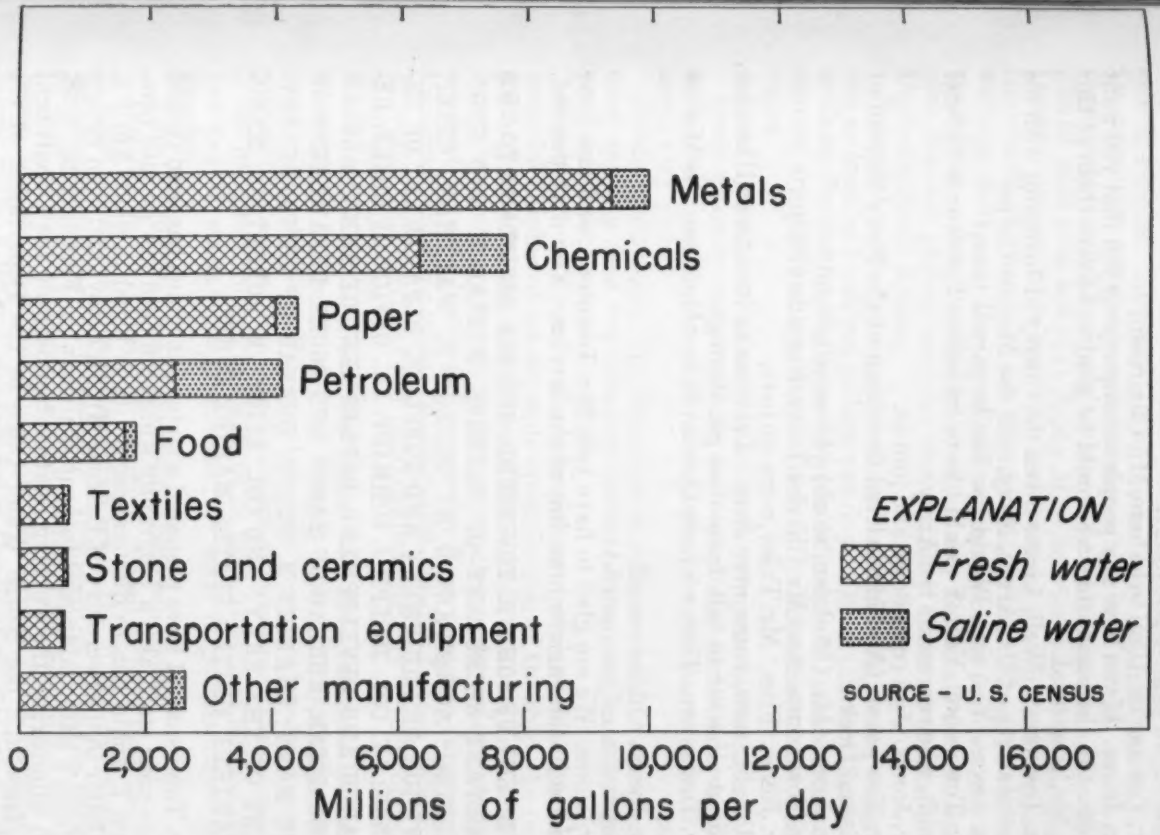
Here, as a matter of fact, is a chart that might interest you.

Water used in manufacturing is broken down in that chart by different industries showing water which is fresh versus saline, to indicate which of the industries uses more or less saline water in connection with its operation.

You will see that those industries that have such important uses of water as cooling are better able to use untreated or unconverted saline water than industries which depend upon water of better quality.

Mr. JONES. Without objection, the chart will be made a part of the record. I think it is a valuable chart and should be used.

(The chart referred to is as follows:)




WATER USED IN MANUFACTURING, 1954

Mr. JONES. Thank you very much, Dr. Leopold.

Now, Mr. John R. Townsend, special assistant to the Assistant Secretary of Defense, Research and Engineering.

We are glad to have you today.

Mr. TOWNSEND. Glad to be here, Mr. Chairman.

Mr. JONES. If you have any people accompanying you that you want to present to the committee, we would be glad to receive them at this time, Mr. Townsend.

Mr. TOWNSEND. Well, I have taken the liberty of bringing with me representatives of the Army, Navy, and the Marine Corps.

Mr. JONES. Yes, sir. Would you like to parade them?

Mr. TOWNSEND. Yes. I would like to introduce Lieutenant Colonel Schmidt, who represents the Army.

Mr. JONES. Just come down and join us.

Mr. TOWNSEND. And Mr. Alfred Goodman of the Navy Bureau of Yards and Docks.

Mr. JONES. Mr. Goodman, would you come around?

Mr. TOWNSEND. And Mr. Charles Tuley, Bureau of Ships.

Mr. JONES. Fine. Mr. Tuley, come up here.

All right, now, come over here. Let's make it informal because we might all want to talk before we get through.

Mr. TOWNSEND. Then we have Colonel Robertson, from the Marine Corps.

Mr. JONES. Off the record.

(Discussion off the record.)

Mr. JONES. We are glad to have you, Mr. Townsend, and also your associates in the various branches of the service. You may proceed.

**STATEMENT OF JOHN R. TOWNSEND, SPECIAL ASSISTANT TO THE ASSISTANT SECRETARY OF DEFENSE, RESEARCH AND ENGINEERING; ACCOMPANIED BY GEORGE B. WAREHAM, CHIEF, DIVISION OF EQUIPMENT AND SUPPLIES, DEPARTMENT OF DEFENSE; LT. COL. JOSEPH J. SCHMIDT, JR., OFFICE OF CHIEF, RESEARCH AND DEVELOPMENT, DEPARTMENT OF ARMY; ALFRED K. GOODMAN, BUREAU OF YARDS AND DOCKS, DEPARTMENT OF THE NAVY; CHARLES B. TULEY, BUREAU OF SHIPS, DEPARTMENT OF THE NAVY; AND COL. ELIOTT B. ROBERTSON, HEADQUARTERS, UNITED STATES MARINE CORPS**

Mr. TOWNSEND. I have prepared a statement which has been turned over to your staff, also a biography which we need not go into here.

First I would like to discuss specific items listed in your April 1, 1958, letter to the Secretary of Defense Mr. McElroy; and then review Dr. Foote's letter addressed to your chairman on February 24, 1958, which summarizes the working relationship between the Department of Defense and the Saline Water Office of the Department of the Interior, and also summarizes the DOD research and development program in this area.

Item A—now this relates to the first question—present and potential military needs for desalting water.

Military requirements for water are, wherever practicable, met from fresh-water supplies such as municipal water systems, lakes, streams, and wells. Every effort is made to develop fresh-water supplies and to purify ground waters before resorting to the more expensive desalting process. However, all of the military departments have need for desalting water at installations which are remote from fresh-water supplies and near a salt water or brackish water source. Examples of such sites are: (1) Army Map Service control in the Libyan Desert; (2), ships at sea; (3) construction battalions at remote islands; and (4), artificial sea islands, such as the "Texas Tower" early warning stations. The quantitative requirements for desalted water vary from a few hundred gallons per day for small detachments to over 200,000 gallons per day for military bases at Bermuda and Dhahran, Saudi Arabia.

Potential needs for desalted water in island and desert areas may run as high as 2 million gallons per day. Other military bases, such as Camp Pendleton, Calif., and Parris Island, S. C., where fresh-water sources are diminishing, may have a large requirement for desalted water.

Item B, optimum size and capacity of equipment for such needs.

Since quantity requirements and operating conditions vary over such a wide range, the size and capacity of equipments to meet these needs vary widely.

Mobile equipment: Optimum sized mobile or portable equipment to meet varying field requirements includes 60-, 200-, and 300-gallon-per-hour vapor compression stills.

Shipboard equipment: The selection of optimum sized distillation units for shipboard use depends upon the size of the ship, the type of steam generating equipment used, the size of the crew, and other factors. Some sizes currently considered optimum for specific shipboard applications are: 12,000-gallon-per-day flush-type, two-stage units for numerous destroyer types; 50,000-gallon-per-day 5-stage units for the *Forrestal* class carriers; and 70,000-gallon-per-day units proposed for the *Enterprise* class.

Permanent installations: Optimum sizes for permanently installed shore-based equipment depend largely upon the quantity requirement. Now 50,000-gallon-per-day units are considered optimum for vapor compression stills. Optimum size for multiple effect evaporators is not definitely known but may be as high as several million gallons per day if military requirements for such large quantities should develop.

Item C, progress toward developing such equipment.

Distillation equipments of optimum capacities have been developed to meet all military requirements except the 70,000-gallon-per-day unit mentioned for the *Enterprise*. Information gained in the development of the 50-000-gallon-per-day flash-type multiple-stage distillation equipment is being used in the current development of the larger unit. I do not want to leave the impression that all of our water desalting problems are solved because they are not. Our requirements for desalted water, however, are being met. The cost is high, equipment maintenance is high, equipment down time is in some cases excessive, equipment weight is excessive, and manpower requirements are too large.

The development program to which I referred earlier is aimed primarily at correcting the deficiencies, improving the overall economy of operation, and evaluating new techniques and equipments for desalting water. The research and development program since World War II has resulted in an increase of the distillate to fuel ratio of the portable vapor compression still from 80 to 1, to approximately 150 to 1, and in operating time without descaling from about 200 hours to 720 hours. Further improvements in efficiency are expected to result from current work on acid-feed injection to reduce scale formation and from methods to utilize waste heat from small diesel engines. The distillate to fuel ratio for the large vapor compression stills installed in Bermuda is approximately 300 to 1. Our engineers inform me that they expect to attain this ratio in the mobile units.

Because of the varying conditions under which these military equipments are used and the methods of accounting employed, it is difficult to arrive at the true cost of desalting water for military use. Best available information indicates that operation and maintenance costs range from $2 to $4.50 per thousand gallons of water produced. This high cost of desalting water demands that we continue to search for more efficient desalting methods.

Item D, localities here and abroad where the efficiency of military activity could be improved by additional supplies of converted sea or brackish water.

There are no localities either within the United States or abroad where the efficiency of military activity could be improved by additional supplies of converted sea or brackish water beyond that which can presently be made available with existing or developmental equipment. The cost is high, but the needed water is being supplied or can be supplied by equipments already developed.

Item E, the extent to which saline water conversion techniques perfected or under development by the Defense Department can be applied to civilian use when disaster interferes with normal local water supply.

Saline water conversion techniques and equipments developed by the military departments could be applied to civilian use under disaster conditions. However, there have been no plans for such use and little equipment is available for such application. The greatest potential for this application is found in Navy ships which, if tied up at the dock, could utilize part of their distillation capacity to supply adjacent communities in time of disaster.

Item F, the extent of coordination and cooperation achieved and planned between the Department of Defense and the Department of the Interior with respect to saline water conversion.

In reply to this question, I refer to Dr. Foote's letter of February 24. In addition to this information, I am pleased to report that the engineers and scientists from the military departments have been working continuously with personnel of the Saline Water Office and that all last week they were working together at Wrightsville Beach evaluating distillation equipments developed by both the Army and the Department of the Interior. The specific equipments to which I refer are a new portable aluminum vapor compression still and a Badger-Hickman rotary still developed under Army and Department of the Interior programs.

In regard to the Department of Defense Research and Development program on saline-water conversion, I would like to refer to Dr. Foote's letter of February 24, starting with the second paragraph:

In compliance with President Truman's March 16, 1950, letter, this Department through a designated representative on the staff of the Research and Development Board compiled a detailed report of completed and active research and development work on saline-water conversion in the various segments of the Department of Defense. The Department of Defense representative's first formal participation in this activity was on April 21, 1950, when he reviewed defense activities on saline-water conversion at a joint conference called by the Department of Interior and attended by representatives of all interested Government agencies.

From the date of this first conference until the approval of Public Law 448 on July 3, 1952, this Department assisted the Department of the Interior by (1) developing information on both military and industrial requirements for water, (2) providing a statement of Defense Department interests in the proposed program, and (3) providing detailed information on Defense Department activity in saline-water conversion.

Immediately after the enactment of Public Law 448 formal liaison was established between the two Departments in accordance with provisions of the law. Subsequent to that time, Defense and Interior Department personnel have held numerous joint conferences for the purpose of developing and conducting a coordinated program. Working level scientists and engineers from the three military departments have participated in several of these joint conferences, including field trips, which have been effective in the planning and pursuit of a program of common interest.

In addition to these conferences which have been held approximately twice each year, close coordination has been maintained through the medium of correspondence, telephone calls, and personal contacts. There also has been a free interchange of technical progress and final reports on projects underway by each department.

I would now like to turn to the addendum of Dr. Foote's letter:

Following is a brief resume of work done by the military departments on the desalting of water—

First under the Army:

The Army Corps of engineers (1) designed and developed a 1,250-gallon-per-hour semipermanent thermocompression distillation unit. This unit was tested at Kindley Air Force Base, Bermuda. As a result of this work, specifications were prepared and four 2,000-gallon-per-hour units were built. These units are now producing potable water at Kindley Air Force Base. Fuel to distillate ratio is approximately 1 to 300 with periodic acid descaling; (2) designed and developed a 125-gallon-per-hour portable aluminum and aluminum alloy thermocompression distillation unit. The object was to eliminate use of critical materials, reduce weight, reduce cost, and simplify. The experimental unit proved satisfactory except for troubles with dissimilar metals. This unit has been redesigned eliminating copper bearing metals in contact with water. A full scale test of the redesigned unit will be made in the near future.

In addition to the above projects, the Army has a general water research project under which it is (1) exploring ion exchange resins; (2) determining limitations of the electrodyalisis method; (3) exploring new techniques; and (4) following industrial developments and the saline water conversion projects being sponsored by the Office of Saline Water of the Department of the Interior.

The Navy.

The Bureau of Ships has a continuing program to develop more efficient and reliable equipment and methods for demineralizing sea water for shipboard and submarine uses such as boiler water makeup, heating system, decontamination, submarine batteries, and drinking water. The program involves new design distillation equipments, including multiple-stage flash-type, vertical basket-type, fluted tube-type, thermocompression-type and an abandon ship still. The effort includes research on corrosion and materials, development of new designs, design and development of components, reduction in the use of critical materials, and the evaluation of commercial equipment. Most evalua-

tion work is done by the Bureau's laboratories. Developmental and construction work is done largely through contract with industry. Following is a partial list of contractors who are now or have recently participated in this program: Maxim Silencer Co., Badger Manufacturing Co., Griscom-Russell Co., Clever-Brooks Co., Arthur A. Crafts Co., Read-Standard Co., Young Radiator Co., and Bethelehem Steel Co.

The Bureau of Ships is also evaluating a small electromembrane dimineralizer for possible submarine use. This unit was developed by Ionics, Inc.

The Bureau of Yards and Docks effort is directed largely to improving the efficiency and reliability of thermocompression distillation equipment for use at shore establishments. This effort has resulted in the development of a number of reliable units in the range of 85 to 200 gallons per hour by several manufacturers.

Scaling is still a problem in all sea water distillation equipment. The Bureau of Yards and Docks is working along with industry, the other military agencies, and the Department of the Interior on this problem.

Under contract with Battelle Memorial Institute it has studied optimum design of components for a thermocompression still. Results of this study are being incorporated into a distillation unit of optimum design. This Bureau is also evaluating two electromembrane demineralizer units—one on sea water and the other on brackish water.

Air Force: The Air Force has no research and development programs on water but depends on the Army engineers for development work in water demineralization equipment. It has, however, a number of new design or experimental water demineralizer units under test for specific application. These include thermocompression distillation plants at Kindley Air Force Base, Bermuda; an Ionics, Inc., electromembrane unit on a "Texas Tower" warning station: and an Ionics unit at P–25, Havre, Mont.

All three military departments are following the Department of the Interior water demineralization program closely for developments with possible military application. One development which promises to have military application is a rotary-type thermocompression distillation unit known as the Badger-Hickman still.

I wish to thank you for this opportunity to present the story, Mr. Chairman.

Mr. JONES. Thank you, Mr. Townsend.

Mrs. Granahan?

Mrs. GRANAHAN. Mr. Townsend, in your statement you mentioned that saline-water conversion techniques and equipments developed by the military departments could be applied to civilian use under disaster conditions, but that there have been no plans for such use and little equipment is available for such application.

In the event of disaster or military attack upon the United States, would not the destruction of potable water at particular localities drastically impair the military potential, and, therefore, is it not important to us for our national defense that further thought be given to this problem by some agency of the Government, whether the Department of Defense, the Civil Defense Administration, or the Department of the Interior?

Mr. TOWNSEND. The answer is yes.

Mrs. GRANAHAN. And yet nothing has been done about it?

Mr. TOWNSEND. That is right.

Mrs. GRANAHAN. Do you not think we should?

Mr. TOWNSEND. Yes; I do. From my experience of being in Germany in 1945, the thing that was most evident on all hands was the lack of water and the extreme difficulty of purifying what water was available locally, and particularly the scarcity of water for hygienic purposes.

Mrs. GRANAHAN. I found that same condition myself in Germany last year.

Mr. JONES. Thank you.

What have been the results of the Bureau of Yards and Docks in their antisaline work? You have had considerable experience with the problem?

Mr. GOODMAN. Yes, sir. We have developed the 85- to 200-gallon-per-hour thermocompression stills. We stock them at the present time, and they are strictly for military use—for the Seabee construction battalions.

Those stills, then, are supplemented with larger stills. We just recently awarded a contract for a still with a capacity of 10,000 gallons per day for the support of our large camps and hospitals during wartime. Those requirements run up to 50,000 gallons a day. And by utilizing several units, we can satisfy those requirements in the field. That is strictly military application.

Mr. JONES. You have also done considerable research in the scaling proposition?

Mr. GOODMAN. We have. Before we got into the work on scale prevention, on an average after about 100 to 150 hours of operation a still had to be shut down and mechanically cleaned. It was quite a job.

We have been able to develop a process by feeding acid into a still periodically to maintain a still in clean condition. I have just received a report from Port Hueneme, Calif., that we have had a still running for 1,000 hours and it has given us economy of 165 to 1, and that still has not been shut down in those 1,000 hours, and it is still running.

We are just at the point where we are ready to send that out to the field and have some installations made in the field and teach the men how to operate the equipment with the installation.

Mr. JONES. How is it——

Mr. GOODMAN. We are using sulfuric acid. We inject a very small quantity of 500 cubic centimeters of sulfur acid mixed 50 percent with water. That is put in as an injection at 1 time about every 8 hours. The cost of that acid runs about 2 cents a thousand gallons, which is a very nominal cost. We have been able to maintain scale-free operation in these thermocompression stills.

Mr. JONES. Do you know anything about the Kindley Air Force Base in Bermuda?

Mr. GOODMAN. No; I do not.

Mr. JONES. That is not a Navy operation?

Mr. GOODMAN. That is right.

Mr. JONES. Mr. Indritz?

Mr. INDRITZ. Have there been any research and development projects of any of the military departments which have been conducted in cooperation with the Office of Saline Water?

Mr. GOODMAN. Only to the extent that 2 years ago we did procure 2 of the Ionics electromembrane units, 1 for brackish water and 1 for some sea water. We met with the Saline Committee and advised them we considered buying those units, and at the same time they thought or the thought was stressed that it was a good idea for someone else to get into this field and do some work on these Ionics membranes.

We have been running tests at Port Hueneme for a year and a half on these two units. Those tests are just near completion right now. We have had very good results with the membrane stacks. We have

had some mechanical failures, which is something that by redesign can be corrected.

With the brackish water unit we have had very good results.

The costs of producing potable water from sea water by this method—now, this is just direct costs—run about $1.47 a thousand gallons using the sea water unit.

I have not received a report on the brackish water unit as yet.

Mr. INDRITZ. Would the brackish water costs be lower?

Mr. GOODMAN. Those are direct costs over and above the cost of the equipment.

Mr. INDRITZ. Is the information derived from those tests being made available to the Office of Saline Water?

Mr. GOODMAN. It can be as soon as I receive the reports. And one report should be in here shortly on the sea water unit.[9] The brackish water unit report should be in within a few weeks.

Mr. INDRITZ. Is it the custom for military departments to do that as a matter of course?

Mr. GOODMAN. They are unclassified. We can make them available to you.

Mr. INDRITZ. Have they been made available in the past?

Mr. GOODMAN. Not yet. The report just came in yesterday.

Mr. INDRITZ. I mean the prior reports that have been made.

Mr. GOODMAN. No.

Mr. INDRITZ. Have they been available to the Office of Saline Water?

Mr. GOODMAN. Oh, yes. Yes; indeed. I send a copy of all those reports to the Office of Saline Water.

Mr. INDRITZ. And you receive information of the studies made by the Office of Saline Water?

Mr. GOODMAN. I do.

Mr. INDRITZ. Do the defense agencies have personnel who are competent in performing research on the various processes that could be made available to the Office of Saline Water by exchange of funds under the Economy Act?

Mr. GOODMAN. Now, do you mean on a loan basis or—let's put it this way: As far as Yards and Docks are concerned, there are men and scientists available within Yards and Docks thoroughly familiar with these problems, and they are working on them at the present time.

Mr. INDRITZ. So that if a project were conceived, upon which both agencies wished to cooperate, that could be done within the framework of the present law and the physical facilities that the Defense Department has?

Mr. GOODMAN. Definitely.

Mr. INDRITZ. Has the Office of Saline Water ever proposed to you a joint research endeavor?

Mr. GOODMAN. It has been discussed, but, as I understand it, their funds were limited, and, of course, we have had, fortunately, sufficient funds to carry on our work. We have done this work with a very small amount of expenditure of money, and we have needed no assistance as far as our work was concerned.

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[9] This report, dated April 8, 1958 (Technical Note N-332) is available in the subcommittee files.

Mr. INDRITZ. But there are some problems that apparently you are both jointly interested in. For example, Dr. Townsend indicated that the Badger-Hickman still, which is being studied by the Office of Saline Water, promises to have military application, and, therefore, it would seem to be of interest to the military departments. He has indicated that the Navy and Air Force are interested in the electromembrane process and that scale is a common problem.

In view of the fact that you have these common problems, would it not be desirable for the two agencies to get together and perhaps work out cooperative agreements whereby they might share the costs of proceeding with such investigations?

Mr. GOODMAN. There is no reason why such arrangement could not be made. I know we would be susceptible to such an agreement.

Mr. INDRITZ. Is it likely that the two agencies may get together to discuss that approach?

Mr. GOODMAN. There is no reason why we cannot.

Mr. INDRITZ. In view of the Bureau of Ships' interest in the electromembrane units, what efforts have been made by the Navy Department to acquire information concerning the work of foreign countries and organizations on this process?

Mr. GOODMAN. I can answer for the Bureau of Yards and Docks but not for the Bureau of Ships.

Mr. INDRITZ. Is there anyone who can?

Mr. TULEY. I am the Bureau of Ships representative. What was the question?

Mr. INDRITZ. The question was that in view of the statement by Dr. Townsend that the Bureau of ships is interested in electromembrane units, to what extent has the Bureau of Ships sought to acquire information as to the researches done in foreign countries and by foreign organizations?

Mr. TULEY. Only by contact with such American companies as Ionics, Inc.

Mr. INDRITZ. Have you had any contact with the TNO organization?

Mr. TULEY. No; we have not.

Mr. JONES. Mr. Indritz, if you will put your question as "all foreign" without saying "membranes," then we will get it all inclusive. And I think that would save a good deal of time.

Mr. INDRITZ. Yes. Well, the question I am really directing this to is the extent to which the military departments have tried to get the advantage of the experience which is being acquired by the foreign countries. What contacts——

Mr. JONES. Do you have the answer to that, Mr. Townsend?

Mr. TOWNSEND. Yes. At the working level there is always a strong desire on the part of the professional people working on these projects to garner information wherever it may be, and we have in the Department of Defense very excellent interchange of information not only between departments but also between United States and foreign governments.

Mr. JONES. On this subject?

Mr. TOWNSEND. On this subject; yes, sir.

Mr. JONES. And there is being constant exchange of information——

Mr. TOWNSEND. That is right.

Mr. JONES. Data and progress reports and scientific papers——

Mr. TOWNSEND. That is correct.

Mr. JONES. And all of those things that would go into stimulating your inquiry into the subject?

Mr. TOWNSEND. This is correct.

Mr. JONES. And you feel that you have exhausted all the known sources of information to satisfy you as to what methods are being pursued in some foreign country where you have information that would be available to you?

Mr. TOWNSEND. Within the limits of human frailty, the answer is "Yes."

Mr. JONES. Now let me ask you the next question. Are you informed as to what the Soviets are doing in the way of scientific research and development on this subject—saline water?

Mr. TOWNSEND. To the extent that information is available, we have access to it.

I personally have not heard a briefing from CIA on this recently. I do not know whether any of the gentlemen here have. Have you, Mr. Tuley?

Mr. TULEY. No; I have not.

Mr. GOODMAN. I have not.

Colonel SCHMIDT. No.

Mr. TOWNSEND. Have you?

Mr. WAREHAM. I have not seen any reports.

Mr. JONES. What is your name, sir?

Mr. WAREHAM. Wareham, from the Department of Defense.

Mr. JONES. What is your title, Mr. Wareham?

Mr. WAREHAM. I am Chief of the Division of Equipment and Supplies. I work directly for Mr. Townsend.

Mr. JONES. Can you give us a reply to the question?

Mr. WAREHAM. In looking through the various intelligence reports which come across our desk, or my desk, I am always looking for any information regarding saline water developments. I have not seen any such reports coming from Soviet Russia.

Mr. JONES. Do you have the reports that were procured by the State Department in the years 1956 and 1957 on the subject?

Mr. WAREHAM. I am sure I have access to them and could get them.

Mr. JONES. Well, now, that is not the question.

Mr. WAREHAM. I do not have them immediately available.

Mr. JONES. I mean "have had them." Did you examine them? The question is: How far have the Soviets gone in this field? Are we keeping up?

You say it is of military importance, that it is for the security and defense of this country. Now, the question is: Is the Congress of the United States going to provide the Department of Defense with every weapon to fight the Soviets? Will we be derelict if we do not give you further authority and more money to pursue the question?

Mr. WAREHAM. May I——

Mr. JONES. Yes, sir.

Mr. WAREHAM. Explain how I would treat this information?

Mr. JONES. Yes, sir.

Mr. WAREHAM. As these reports come across my desk, I am always looking for reports of this nature in the areas of equipment and supplies, which include water supply. When I find any note, any intelligence item, reporting work of this nature going on any place outside of the United States, I call this to the attention of the military departments who are working in this area, who are responsible for conducting the research and development in this area. I pass this information on to them to follow up for what it is worth in the development of their programs.

Mr. JONES. Now, we will come back to the question. Have you transmitted to any of those agencies of the Defense Department any information that would disclose that we are behind the Russians in this scientific field?

Mr. WAREHAM. I have not, in specific answer to that question.

Mr. JONES. Yes, sir.

Mr. WAREHAM. The information that we are behind. No; I have not.

Mr. JONES. You have not?

Mr. WAREHAM. No.

Mr. JONES. Have you rationalized on the proposition based upon the information that has come to your attention or is available to you?

Mr. WAREHAM. Could you put that question in a different way? I am not sure that I understand you, Congressman.

Mr. JONES. Do you know what the Russians are doing——

Mr. WAREHAM. I do not.

Mr. JONES. In this field?

Mr. WAREHAM. I do not.

Mr. JONES. Do you know if there is information available to you gathered by our Government that would inform you as to the progress the Russians have made? Does the State Department, or the Office of Saline Water? Or the Secretary of Defense? Has he any information that you could get to inform you as to whether or not the Russians are ahead of us or we're behind them in this program?

Mr. WAREHAM. Oh, he may have. I have not investigated.

Mr. JONES. You have not investigated?

Mr. WAREHAM. That is right.

Mr. JONES. Now, Mr. Townsend, as a representative of the Department of Defense, would you kindly attempt to supply this information as to whether we are lagging——

Mr. TOWNSEND. I will.

Mr. JONES. As compared with the Soviets?

Mr. TOWNSEND. A very good question. I will.

Mr. JONES. Nobody is asking you for secret information or confidential information or any information other than to let us know where we stand relative to the station that the Soviets have achieved.

Mr. TOWNSEND. I will.

(The material requested was furnished by the Department of Defense and appears in appendix A, item 7, p. 286.)

Mr. JONES. Now, that is not asking too much, is it?

Mr. TOWNSEND. No; it is a good question.

Mr. JONES. All right. Because if we are behind them, then we have got plenty of reason to accelerate the program, and if we are not then we can be a little bit more leisurely about it.

But it is a fact that the Saline Water Act directs the Interior Department to work with Defense for the security interests of the country.

Now, I suppose this question comes back to you, Mr. Wareham. Is information obtained by Defense from foreign countries transmitted to the Office of Saline Water?

I am having a hard time getting through to you. I do not know whether I am off the beam or you cannot hear. I do not know which.

Mr. WAREHAM. I have heard you, Congressman. I was reflecting, trying to think whether or not I had transmitted specific information to Mr. Jenkins' office on notes that I have read about foreign programs. I have so many of these from day to day.

I do recall calling Mr. Jenkins and asking him about whether or not he was familiar with some program that was going on down in South Africa. I found out that he was familiar with that. And I believe that I picked this bit of intelligence up from some intelligence document that went across my desk. This is the one single thing which I remember. I may have done this on other occasions.

Mr. JONES. Well, I understand it would be hard for you to keep in your head every transaction relating to every phase of the work, but I believe there is a legal requirement for you people to cooperate with the Office of Saline Water and for them to cooperate with you.

Section 3 of Public Law 448 of the 82d Congress provides that—

> Research undertaken by the Secretary of the Interior under the authority contained in this Act shall be coordinated or conducted jointly with the Department of Defense to the greatest practicable extent compatible with military and security limitations, to the end that research and development under this Act which are primarily of a civil nature will contribute to the defense of the Nation and that research and development in the same field which are primarily of military nature and are conducted by the Department of Defense will be made available to advance the purposes of this Act and to strengthen the civil economy of the Nation.

Now, since that is a directive to the Department of Defense, I wonder if you would be kind enough to comment, after you review your files, if you are complying with section 3 of that act in the Department of Defense.

Mr. WAREHAM. I would like to comment now that we have passed all information on the three military departments' research and development program on to Mr. Jenkins' office. We have done this by forwarding reports from the military projects to his office as they become available. We have done it by informal conferences. We have done it by meeting with his group on field trips. There has been a very free exchange of information.

Mr. JONES. Well, fine. That is what we——

Mr. WAREHAM. Your previous question dealt with information on foreign programs.

Mr. JONES. Yes, sir.

Mr. WAREHAM. And I was not able to give you a very concrete example of information on foreign programs that we have passed over to him.

Mr. JONES. Yes, sir. Well, fine. Mr. Townsend, do you have any recommendations to make to the committee that would improve the two public laws that have been the subject of our discussions today?

Mr. TOWNSEND. No, sir. I would, however, like to make a statement with regard to basic research that would supplement the rather excellent testimony that I have heard here this afternoon. I would like to make two points.

Mr. JONES. Yes, sir.

Mr. TOWNSEND. The first point is in any basic research project there is a minimum amount of effort that can be expended upon the project in order to achieve success. What I mean by that is this: Knowledge and experts are divided up among various disciplines, and if a problem involves both normal chemistry and organic chemistry, you need 2 kinds of chemists if you are going to get a solution to a problem that falls between the 2 disciplines.

The first point, then, is that any basic research project should be studied and manned up with a minimum number of people competent to achieve a result based on their disciplines.

The second point I would like to make is that it is very difficult indeed to state what a minimum basic research program should be. It varies all the way from 5 to 10 percent. But on a continuing or a going basis it would seem that the usual habit is about 5 percent. But when there is a scientific breakthrough, then it is highly essential in order to save time and in some cases to get a result at all to put a large amount of effort on that project in order to achieve a result in a reasonable time. All research directors understand this.

And these are two important points that I have not heard brought up before this afternoon.

Mr. JONES. Well, thank you very much, Mr. Townsend.

Now, if we do have a breakthrough, are you satisfied it is going to take more than a million dollars a year to make proper development?

Mr. TOWNSEND. Well, this is a speculative thing. If you did get a breakthrough, you would want, all other things being equal, to accelerate effort, and you can only do this with more manpower and equipment. And this would require more money.

Now, there ought to be a flexibility, therefore, in the law, that would permit, in the event of a scientific breakthrough, the quick use and deployment of money and effort to bring the thing to fruition.

As I understand the present cold war, it is more of a contest of scraping the bottom of the scientific barrel and getting the latest thing in use than anything else.

So time is of the essence, and it would seem to me when a scientific breakthrough occurs there ought to be provision allowed in the law and in the financing to immediately and quickly take advantage of this opportunity.

This does not mean, on the other hand, that we should provide a tremendous amount of money all the time for basic research, as admirable as that may seem, but we should have enough money for a continuing review of the field so that when there is a scientific breakthrough it will be recognized and can be exploited.

Imagination, as I understand it, is based on a broad technological culture that would allow you to perceive the value of an innovation.

Mr. JONES. Well, do you not think then the legal restriction on the expenditures for management is too low?

Mr. TOWNSEND. I think it ought to be a little higher. I think that has been the consensus expressed here.

Mr. JONES. And that the restriction of 20 percent per year of the total authorization is too low?

Mr. TOWNSEND. I think it is a little low; yes.

Mr. JONES. So you agree with Dr. Schroeder?

Mr. TOWNSEND. I do.

Mr. JONES. In his testimony as to those two specific items?

Mr. TOWNSEND. Yes, sir.

Mr. JONES. It should be the subject of amendment to give the Office of Saline Water wider latitude to carry out this research work?

Mr. TOWNSEND. That is correct.

Mr. JONES. Do you have any further observations to make, Dr. Townsend?

Mr. TOWNSEND. No.

Mr. JONES. Well, gentlemen, do you have anything?

Colonel SCHMIDT. No, sir.

Mr. GOODMAN. No, sir.

Mr. JONES. You know, Mrs. Granahan, I want to make this observation. I guess it has occurred to you time and time again in attending meetings. It is to me a very satisfying thing to find so many dedicated people in the Government of the United States.

Now, we have sat here for 2 days, and we have seen the people of the Government agencies who are able and capable and qualified and who are giving a great deal of thought and devotion to their work. I think it is one of the most refreshing things in the world. If the people of the United States could come here and listen to the fine witnesses and the very learned way in which they have gone about their jobs, I think there would be greater confidence in the central Government.

I wish everybody could enjoy the opportunities that we have had.

Thank you very much.

Now, I am sorry that we have run a little bit long. We have one more witness. I see that is Mr. Gilbert Levin, and I see that you are a resident of Washington, D. C., sir.

Mr. LEVIN. That is right, sir.

Mr. JONES. So would you be kind enough to call on us at 10 o'clock tomorrow if it will not inconvenience you too much?

Mr. LEVIN. I have an appointment out of town, sir.

Mr. JONES. Well, when do you expect to return to Washington?

Mr. LEVIN. Well, it is in the area. I would be back in Washington tomorrow evening. Perhaps Friday——

Mr. JONES. Friday?

Mr. LEVIN. Yes, sir.

Mr. JONES. Could you meet with us then Friday at 10 a. m.?

Mr. LEVIN. Yes.

Mr. JONES. Fine. We will be here, and we will be expecting you.

Thank you very much.

The subcommittee will adjourn now until 10 o'clock tomorrow.

(Whereupon, at 5:04 p. m., the subcommittee adjourned, to reconvene at 10 a. m., Thursday, April 17, 1958.)

# SALINE WATER PROGRAM

## (Research and Development)

THURSDAY, APRIL 17, 1958

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON PUBLIC WORKS AND RESOURCES,
OF THE COMMITTEE ON GOVERNMENT OPERATIONS,
*Washington, D.C.*

The subcommittee met, pursuant to adjournment, in room 1501, New House Office Building, at 10:05 a. m., Hon. Robert E. Jones (chairman of the subcommittee) presiding.

Present: Mr. Jones, Mr. Dawson, Mr. Moss, Mr. Fascell, Mrs. Granahan, and Mr. Knox.

Also present: Arthur Perlman, staff administrator; Phineas Indritz, subcommittee counsel; and Miles Q. Romney, professional staff member.

Mr. JONES. The subcommittee will come to order.

Let me state this morning to the witnesses who are to testify today, the Chair is going to make every effort to try to hear all of those in attendance. If you do have extended statements, I would appreciate it very much if you would summarize your statements and then make additional observations that you think are pertinent to the subject.

Now, yesterday we completed all of the scheduled witnesses except Mr. Levin, who is going to be with us at 10 o'clock tomorrow morning.

To those of you who have come some distance to attend this meeting, we are going to try to be as generous with you as we possibly can, because we know your being here is a great effort and inconvenience. My asking you to summarize your statement if it is extended does not mean that it would not be of interest to the members of the subcommittee in the compilation of the record. All the statements will be placed in the record.

Our first witness today is Mr. Clyde L. Blohm, manager, research division, the Fluor Corp., of Los Angeles, Calif.

Now, will you come over here, Mr. Blohm.

Mr. Blohm, do you have a prepared statement?

### STATEMENT OF CLYDE L. BLOHM, MANAGER, RESEARCH DIVISION, THE FLUOR CORPORATION, LTD., LOS ANGELES, CALIF.

Mr. BLOHM. Mr. Chairman, I have; and I have already submitted to you some 25 copies of it.

I propose to just summarize briefly the prepared statement and make a few additional comments.

Mr. JONES. Yes.

(The prepared statement of Mr. Blohm follows:)

STATEMENT OF CLYDE L. BLOHM, MANAGER, RESEARCH DIVISION, THE FLUOR CORPORATION, LTD., LOS ANGELES, CALIF.

On March 26, 1958, in response to his inquiry of February 20, I forwarded to the Honorable Robert E. Jones, chairman of the subcommittee, a corrected, written statement on the entitled subject. I presume that this document will be made a part of the record of these hearings and, therefore, I do not wish to burden the committee's attention with repetition of its contents. I should like, however, to add a few supplementary comments.

In the course of the studies on saline water conversion processes which our organization has conducted, we constantly have been impressed by the lack of realism in the many references to costs of potable water appearing in the press and elsewhere. The great variation in quoted costs applies not only to the potential recovery of water from saline or brackish supplies, but also to the provision of supplemental water from natural sources. We believe that continued emphasis needs to be placed on the correction of many erroneous inferences drawn from these frequently inaccurate quotations.

The Office of Saline Water has contributed considerably to the standardization of cost methods which has aided in making better comparisons on a common basis of various conversion processes. This procedure is fully described in A Standardized Procedure for Estimating Costs of Saline Water Conversion, Office of Saline Water, March 1956. Since the issuance of said procedure there has been some criticism of the cost bases specified. However, further inspection of the procedure makes it clear that such bases were adopted only as a point of departure and that as better or revised cost information is developed, it should be substituted for the bases specified, with suitable explanation of the reason for the differences. At the same time, use of the Office of Saline Water procedure has permitted relative comparison of many cost analyses of different processes; although the absolute cost figures may be somewhat in error, if for no other reason than the economic inflation that has occurred since the procedure was issued.

The cost of production of potable water by any of the processes currently being considered, whether they be distillation, membrane, or others, always refers only to the production cost of the water at the plant site. By the same token, quoted costs of natural water supplies frequently refer only to the delivery of such water to a central reservoir. In any practical application, it must be obvious that to such basic production costs must be added the costs of distribution. While it is true that today there are sea-water conversion plants in actual operation in Kuwait and on islands in the Caribbean which are supplying potable water for domestic and industrial use, the installation of any such similar plant in the United States must consider the delivery of the finished product to consumers generally located at some distance and at elevations above the sea level source. In this connection, it might be pointed out that a very approximate calculation indicates that a system for delivering 10 million gallons of potable water a day a distance of 25 miles to a reservoir located at an elevation of 800 feet above sea level would add something in the order of 12½ cents per thousand gallons to the cost of the water. On the other hand, if the converted sea water could be used essentially at sea level in exchange for presently used water which is available and, therefore, capable of diversion to higher elevations, such distribution costs would not be such a serious consideration.

While the foregoing discussion may not appear to have any direct bearing upon the activities of the Office of Saline Water, we know that that Office is well aware of the considerations contained therein. Full cognizance of the many ramifications of the problem furnishes constant stimulus to the necessity for continuation of research and developmental investigations aimed toward the reduction of actual production costs. For this reason we feel it imperative that the Office of Saline Water be provided with sufficient funds to be able to sponsor additional fundamental, pilot plant, and detailed engineering studies to augment any information that may be derived from the recently proposed construction and operation of a demonstration or prototype plant. Such research effort should be directed at basic studies into the mechanism and control of scale formation, into the search for new and less expensive materials of construction, and into the improvement of equipment design and the application of new heat sources, such as low-temperature nuclear reactors. Some money

should be spent continuously for the exploration of new approaches to the saline water conversion process in the expectation that a technological breakthrough, which would have a major impact on the problems, may be achieved. An analogy might be drawn from the pharmaceutical industry. Thirty years ago, all of the common vitamins were made commercially by complicated processes which extracted the materials from natural sources. Over the intervening period, nearly all of these vitamins have now been produced by chemical synthesis with the result that the costs have gone from the level of dollars per gram to, in many instances, a few pennies. Continued operation of the early natural extraction plants, even though they were considered commercial installations, would never have led to this dramatic cost reduction. It was only through sustained research efforts of the academic and industrial laboratories that this achievement was accomplished. In like manner, we believe with today's technology that a satisfactory saline water plant can be built in some specific location which would supply water at an acceptable price. However, only by continuing to invest in research and development can we expect that the cost of such water may ultimately become truly competitive with water from natural sources.

I have spoken principally about saline water distillation since this is the area in which our company's activities have largely been directed. The comments, however, are equally applicable to any of the other processes that have been considered by the Office of Saline Water, and continued study of such alternative processes should be maintained, at least until such time as they may be proved unattractive.

The Office of Saline Water has been largely instrumental over the last 5 years in bringing saline water conversion nearly to a point of practical commercialization. We believe that this success has been achieved by deliberate and careful consideration of the many processes that have been suggested. The final selection of several potentially attractive processes has been made by careful study and not by wishful thinking. While the rate of progress may be somewhat less than desirable, we believe that the rate has been limited largely by the lack of funds. While it is true that many kinds of research must proceed at a limited pace, greater availability of funds for additional development would undoubtedly expedite the ultimate commercialization of saline water conversion.

We in southern California have a long-term concern over future supplies of water. We believe that the Office of Saline Water's activities are leading us toward a possible amelioration of some of this concern and feel that the continuation of these efforts is important to our local, as well as national, welfare.

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SUPPLEMENTAL STATEMENT OF CLYDE L. BLOHM, MANAGER, RESEARCH DIVISION, THE FLUOR CORPORATION, LTD., LOS ANGELES, CALIF.

From my written and verbal testimony, it can readily be observed that my principal interest in commenting to the committee was to present our feelings regarding the Office of Saline Water operations. I dwelt principally on the cost considerations. I spent no time discussing the merits of our own activities.

However, in the interest of completing the record, I should like to make a few further comments.

I do not believe it is possible to place too much emphasis on the matter of cost goals. While I don't want to minimize the importance of basic research and development in search of a possible technological breakthrough, it is unrealistic at this time to endeavor to set some fixed dollar cost target. There are many areas in the United States and abroad in which water could be economically attractive at a cost of $1 per thousand gallons, or even higher. This is particularly true if sufficient education of those concerned can be provided to permit recognition of the real cost of water, including all the hidden costs frequently ignored in natural water supply systems. Therefore, we believe that it is quite practical at this date to construct and operate economical saline water conversion plants based on currently available processes and technology.

With regard specifically to the role of the Fluor Corp., Ltd., in the saline water conversion program, it can offer two distinct advantages to those interested in either pilot or full-scale operating plants. By virtue of our many years of experience in the design, engineering, and construction of plants covering a broad spectrum of the process industries, we are able to provide realistic cost analyses that are based on actual, current industrial practices.

Finally, the Fluor Corp. does not manufacture evaporators or other saline or brackish water equipment. Neither does it have interest in any proprietary process. As a result, it is in a unique position to provide a completely objective and unbiased engineering analysis and opinion on the optimum plant for a specific set of conditions. This can include not only the desalting cycle, but also the source of energy, i. e., whether or not the process should be coupled with an electrical powerplant, a low temperature nuclear reactor, or some other energy generation.

Again, I should like to reaffirm my statement that the Office of Saline Water has been cooperative. It has contributed substantially to the progress of the development toward commercialization of saline water conversion processes and equipment. Its activities have been constrained by the lack of funds and certain limitations on their use as contained in the present law. The program of the Office of Saline Water should be given the means, through additional funds and flexibility of operations, to accelerate the program in directions which they consider most appropriate, but particularly in further research, development, and the sponsorship of at least some "blue sky" concepts.

Mr. BLOHM. My name is Clyde L. Blohm. I am manager of the research division of the Fluor Corp., Ltd., of Los Angeles.

We have been engaged in work for the Office of Saline Water for the better part of the last year doing engineering analysis work on distillation processes with particular emphasis toward the possible application of low temperature nuclear reactors as a heat source.

I have not emphasized our own work particularly in my prepared statement but have chosen to make some more general comments about the program.

In the course of our work, we have been considerably impressed by the great amount of controversy that there is in talking about costs of water, and this is one subject that I feel needs additional emphasis in the further work of the Office of Saline Water in the whole water program.

We have found that many of the costs that have been quoted in the public domain have been unrealistic. They have not taken account of financing considerations. In many instances, these matters have been simply neglected in talking about costs and only the costs of fuel and direct plant costs have been mentioned. This, of course, gives an erroneous impression of the actual cost of the final water.

These cost considerations transfer also over into the costs that are quoted for natural water supplies in many instances in which the costs of financing of natural supply systems are hidden in taxes and other kinds of financial arrangements that do not show on the individual's water bill. This is true in my own case in Los Angeles, and we know of many cases where it is true across the country.

Mr. JONES. Mr. Blohm, are you of the opinion that they are usually low in the estimates?

Mr. BLOHM. I think this is very frequently the case, Mr. Chairman.

Mr. KNOX. Now——

Mr. JONES. Mr. Knox.

Mr. KNOX. On that point, Mr. Chairman, who is low? The municipally owned plants or this new construction for saline water?

Mr. BLOHM. Both actually.

Mr. KNOX. In other words, it does not reflect the full cost as far as the municipalities are concerned?

Mr. BLOHM. That is correct, sir.

Mr. KNOX. And you feel also that the costs that have been developed so far have not included the full cost of the operation?

Mr. BLOHM. In many instances this is true, I think.

Mr. JONES. You are talking of the cost methods?

Mr. BLOHM. The cost methods, that is correct. The length of amortization time—for example, many municipal systems currently in existence are written off over extremely long periods of time—50 or 75 years, perhaps even 100 years in some cases. They were built frequently many, many years ago. Actual costs in those days were quite a bit lower than they are today, as we are all aware. So the cost of water today that is being charged from those systems is not realistic on a basis of present-day water costs and cannot, therefore, be compared directly with what it might cost to obtain potable water from the sea under today's situation.

Mr. JONES. Have you had an opportunity to observe the activities of the Office of Saline Water, Department of Interior?

Mr. BLOHM. Yes, sir.

Mr. JONES. Are you of the opinion that they are doing a good or bad job?

Mr. BLOHM. I think they are doing a good job with the limitations they have on their operations.

Mr. JONES. All right, what limitations do you have in mind?

Mr. BLOHM. Largely financial, I think, sir.

Mr. JONES. Have you examined the law under which the operation is carried on?

Mr. BLOHM. Yes, sir.

Mr. JONES. Do you have any suggestions to make to the committee as to how that could be improved?

Mr. BLOHM. I think the law is probably adequate the way it stands, but there needs to be more actual funding of the operations.

Mr. JONES. Do you think the 20 percent limitation per annum should be removed?

Mr. BLOHM. Yes, sir.

Mr. JONES. And if the 20 percent factor of development were removed, they would have greater latitude in that?

Mr. BLOHM. I think the Office of Saline Water should have as much latitude as possible to administer their fund as they see necessary.

Mr. JONES. Do you think the contracting procedures are efficient?

Mr. BLOHM. From what I have seen, I would say yes.

Mr. JONES. Do you think that the entire subject matter is of such importance that it should be accelerated over and beyond that which is carried on at the present time?

Mr. BLOHM. I think that the water problem across the Nation is of sufficient importance that there should be some acceleration, particularly——

Mr. JONES. I am talking about saline water now.

Mr. BLOHM. Saline water, yes, particularly in the direction of additional research and development funds for the exploration of new processes.

Mr. JONES. Now, I believe the appropriation item was $825,000 for fiscal 1958. Of that $825,000, only $25,000 was expended for basic research.

Do you think that figure is too low?

Mr. BLOHM. Yes, I do.

Mr. JONES. And do you think that basic research should share a greater apportionment of the money to carry on research?

Mr. BLOHM. Right. Of course, there is always the matter of semantics, as far as basic research is concerned; but I do feel that there are still areas in studying the mechanism of scale formation and the investigation of new materials for construction, and corrosion control, and matters of this kind, that need considerably more investigation.

Mr. JONES. Are you familiar with the experiments now being conducted at the University of Michigan on the scale problem?

Mr. BLOHM. Not University of Michigan, sir. I am sorry, I am not familiar with it.

Mr. JONES. All right, Mr. Knox.

Mr. KNOX. May I inquire from your observation and your actual work in this field, has the Office of Saline Water, Department of Interior, made any major contribution toward your efforts as far as your company is concerned?

I am not speaking of dollars.

Mr. BLOHM. I am not quite sure I understand you, sir.

Mr. KNOX. Well, undoubtedly your company is interested in developing the processing of sea water into drinking water or water for consumption. Undoubtedly you have been in contact, have you not, with the Department of Interior Saline Water Office?

Mr. BLOHM. Yes, sir. Oh, yes, sir.

Mr. KNOX. What contribution have they made in Government to assist you?

Mr. BLOHM. Well, they have been extremely cooperative in supplying us with all of the background information that they have accumulated over the period during which their Office has been operated, and this has been useful to us in permitting us to make our own study under contract with them more efficient.

Mr. KNOX. In other words, then, the Office of Saline Water have made available to you the information which they have received from contracts with universities and other corporations?

Mr. BLOHM. Yes, sir.

Mr. KNOX. Under contract with the Saline Office?

Mr. BLOHM. Yes, sir.

Mr. KNOX. In other words, you feel, then, that there has been a cooperative spirit on behalf of the Department with your company?

Mr. BLOHM. Very much so. As a matter of fact, we have submitted several proposals to the Office of Saline Water for some schemes of our own; and they have given all of these careful consideration, have returned to us their criticisms, and generally have cooperated to, I think, the fullest extent in all of our dealings.

Mr. KNOX. Are you familiar with the California law relative to assistance that they may be given now toward the development of the saline-water project, financially?

Mr. BLOHM. I am not familiar with this in any detail; I have not read the law, but I know about it.

Mr. KNOX. But the State of California is making a major contribution, are they not?

Mr. BLOHM. They are proposing to make a major contribution. I do not know where that stands at the moment. I talked to Mr. Banks last Friday and he indicated that the legislature was still in session and part of their discussion still revolved around the water-program financing for the next year.

Mr. KNOX. I understand that the California Legislature has adjourned and that they have left this question of water still pending before a conference committee.

Mr. BLOHM. I think that is correct, sir.

Mr. KNOX. And that the Governor of California called the legislature back into special sessions; is that correct?

Mr. BLOHM. I think so; yes.

Mr. KNOX. You have hopes that they are going to be able to reach a compromise?

Mr. BLOHM. I do not know how strong these hopes are. I have hopes, yes, but I am not too sanguine as far as my expectations are concerned.

Mr. KNOX. Of course I am hopeful also that they will, because I know it is something California is vitally interested in.

Mr. BLOHM. Very much so.

Mr. KNOX. To make a contribution toward the development.

Mr. BLOHM. Right.

Mr. KNOX. That is all.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. Mr. Blohm, has there been much delay by the Office of Saline Water in acting on successive stages of the proposals of your company?

Mr. BLOHM. No; I do not believe that I can say there has been any appreciable delay as far as their capability to act. We have, as I said, several proposals in their Office and these have not moved as rapidly as we would like to see them move primarily for the reason that again funds have been limited.

Mr. INDRITZ. Such delay tends to discourage or impair the effectiveness of your company's operations?

Mr. BLOHM. It does for the reason that we have a team of engineering experts that have been working in this field; and, without continuation of this effort, we have to employ these people elsewhere. It disturbs our own planning and operation.

Mr. INDRITZ. And does it also delay achievement of the desalinization projects?

Mr. BLOHM. Certainly.

Mr. INDRITZ. So if the Office of Saline Water had more personnel, more funds to act more rapidly on these project proposals, your work could be expedited as well as the whole program?

Mr. BLOHM. Yes, sir.

Mr. INDRITZ. Thank you. You are familiar that under the basic act of the Office of Saline Water, there is a limitation of 20 percent on the administrative expenses which the office may——

Mr. BLOHM. I did not recall that, I am sorry.

Mr. INDRITZ. If such a limitation were imposed upon the activities of your company, would it be a very marked handicap to the research work of your company?

Mr. BLOHM. Yes, our administrative burden is somewhat higher.

Mr. INDRITZ. Do you believe, therefore, that this limitation should be removed from the statute in order to make the Office of Saline Water more efficient and effective?

Mr. BLOHM. I think to the extent that the Office of Saline Water is able to draw on outside contractors that are competent, they can perhaps operate effectively under this percent limitation.

On the other hand, if it is their responsibility to do more of the evaluating of new proposals and the status of processes in their own staff, then the percent limitation undoubtedly is too low.

Mr. INDRITZ. And such——

Mr. JONES. Just a minute.

Mr. INDRITZ. Yes, sir.

Mr. JONES. You say that those delays are causing you some inconvenience, and yet the limitation of management cost is the very thing that is keeping them from expediting consideration of your proposals.

Mr. BLOHM. I am sorry, Mr. Chairman. Perhaps you misunderstood me when I referred to the delays. I do not feel that the delays are administrative as far as the Office is concerned, but only the fact that they have not had money to fund the new proposals that they have actually said that they would like to see go ahead.

Mr. JONES. I see, yes. Thank you. That does clear it up. Any further questions?

Thank you very much, Mr. Blohm.

Mr. BLOHM. You are welcome.

Mr. JONES. Dr. Edward G. Fochtman, supervisor, chemical engineering research, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.

That is quite a title, Dr. Fochtman.

## STATEMENT OF DR. EDWARD G. FOCHTMAN, SUPERVISOR, CHEMICAL ENGINEERING RESEARCH, ARMOUR RESEARCH FOUNDATION OF ILLINOIS INSTITUTE OF TECHNOLOGY, CHICAGO, ILL.

Dr. FOCHTMAN. Yes, it is.

Mr. KNOX. Mr. Chairman, was the prepared statement of Mr. Blohm inserted in the record?

Mr. INDRITZ. Yes, sir.

Mr. JONES. Yes. Without objection all the statements of the witnesses that appear today will be inserted in the record prior to their statement if not otherwise noted.

You go ahead, Dr. Fochtman. We are glad to have you.

(The prepared statement of Dr. Fochtman follows:)

STATEMENT OF EDWARD G. FOCHTMAN, SUPERVISOR, CHEMICAL ENGINEERING RESEARCH, ARMOUR RESEARCH FOUNDATION OF ILLINOIS INSTITUTE OF TECHNOLOGY, CHICAGO, ILL.

The following is a statement of Edward G. Fochtman, supervisor, chemical engineering research, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill. The Armour Research Foundation is a not-for-profit research organization with a technical staff of approximately 850 technical employees and conducts approximately $12 million of contract research yearly. This research is sponsored by both Government and industry and covers all fields of physical science.

PREVIOUS EXPERIENCE

One of the sponsored research programs conducted by our organization was sponsored by the Office of Saline Water under contract No. 14-01-001-83. This relatively modest program, with a total appropriation of approximately $5,700, concerned the partial pressure distillation of water with water immiscible solvents. The proposal for this program was submitted April 22, 1955. The program was initiated May 23, 1956, and terminated November 22, 1956. The

program was entirely a study program and did not involve experimental work. The objective was to investigate the feasibility of a partial pressure distillation scheme, which offered an advantage over other known processes in that a lower temperature could be used for evaporation of the water and thus scale-forming tendencies would be reduced. Our studies indicated that this idea was inherently uneconomical due to relatively large heat loads and the equipment costs involved. The process was compared on an economic basis with vapor compression distillation, vacuum evaporation and solar evaporation. In each case the cost estimate from preliminary consideration indicated that the proposed partial pressure distillation was not economical.

More recently we have engaged in the study of water sources in the Tularosa Basin of New Mexico and of various means for purification of brackish water in this basin. During this study published literature was reviewed for its applicability to the purification of brackish water. Limited experimental work was conducted to establish the feasibility of one proposed method of purification of the brackish water in this area. Results of this experimental work were inconclusive and served only to indicate further work on the demineralization of brackish water is required to insure a feasible engineering design of equipment.

During both of these studies we found the staff of the Office of Saline Water to be most cooperative in supplying us with information, encouraging the submission of research ideas, assisting in evaluation of potential conversion processes, and discussing technical aspects of the problem.

## RECOMMENDATIONS

Recommendations are based on the experience outlined above and a general knowledge of research techniques and methods which has been acquired during the course of extensive research studies on a wide variety of problems.

Our recommendations can be classed in four separate groups: 1. Problem definition; 2. Basic research; 3. Pilot plants; 4. Methods.

Each of these is discussed briefly below.

### *1. Problem definition*

Although it is generally agreed that the conversion of saline water will be necessary for the continued economic growth of the country, there appears to be a lack of a firm estimate as to the degree of urgency of the problem. It is recommended that efforts be made to fully assess the extent of the problem, the solutions which would be considered satisfactory, and the time at which the problem will be critical for given areas in the United States. Such a study would determine the relative worth of potable water in certain typical local areas. Work to date has been directed toward fixed cost goals, however, some areas may be capable and willing to pay more for potable water. Efforts should be made to locate these areas and promote the use of saline water conversion as a source of potable water.

### *2. Basic research*

There is a continuing need for the evaluation of processes which may be applicable to the conversion of saline water. The Office of Saline Water has, during the past few years, evaluated literally hundreds of suggestions for purification of water and has requested additional ideas from individuals, industry, research organizations, and other Government agencies. These efforts should be continued in order to take advantage of new developments in our rapidly expanding technology. In addition, some of the processes now under study should be examined more extensively in an attempt to better understand the mechanisms involved and to utilize this understanding in the development of a more feasible process. At the present time, it is believed that considerable efforts should be expended in the study of purification by freezing, and in the development of electrodialysis equipment. Since scale formation of sea water and of brackish water represents one of the major obstacles in the operation of evaporation plants, it is recommended that efforts to better understand the nucleation of scale formation and the mechanism of deposition on heating surfaces be greatly expanded.

Although primary emphasis in the past has been concerned with saline water it is suggested that these studies be expanded to include brackish water of various chemical compositions.

*3. Pilot plants*

I am not particularly familiar with the present pilot plant program and believe that others appearing before this committee can give details pertinent to the present program. There are reasons why consideration should be given to further pilot plant studies for solar distillation of saline and brackish water.

The electrodialysis method of water purification is believed to hold considerable potential for areas having brackish water supplies. This method has not been adequately evaluated for brackish water of various salt compositions. Pilot plants, either of present commercially available types or of new design, should be developed, constructed and operated in a number of areas having brackish water supplies.

*4. Methods*

It has been our experience that the time lapse between submission of a proposal and granting of a contract by the Office of Saline Water is excessive. The reason for this is not clear to us but apparently involves a very careful screening of all ideas submitted before granting a firm research commitment. This delay has a tendency to discourage the submission of ideas and to cause research personnel to lose interest in the problem of saline water conversion. Such a system may also discourage the submission of "blue sky" ideas since they must be defended to a large number of experts in the field. It may be desirable to give the Office of Saline Water more latitude in granting limited funds for a certain amount of high risk research in order to encourage new approaches to the problem and develop new ideas for saline water conversion. The present method of review is certainly justified for the larger research proposals.

Some means should be found for greater participation in foreign studies and for keeping abreast of foreign developments since a number of countries have similar problems that are much more critical than the present United States problem.

The broad objectives of the program should be reviewed on the basis of present technical and economic information. These objectives should serve as a guide to the Office of Saline Water and this committee in preparing definite plans for expenditures. Those processes which appear to have reasonable economic possibilities should be investigated on a pilot scale basis to determine the costs involved in the purification of both brackish and saline water.

It has sometimes been suggested that the Office of Saline Water Conversion should hasten progress by bypassing the pilot plant development stage of several promising processes and build instead large demonstration units. Such procedures have been used with success on military development projects such as atom bomb processing. The problem of developing a military process is relatively easy because cost is not the most important consideration whereas the chief obstacle for a saline water conversion process is the requirement that it be economic.

Work intended to find means of lowering the cost of a particular process is best done on a small, or pilot scale. Such work requires evaluating various materials as well as various modifications of the process and of the equipment. To do this work on an unnecessarily large scale simply increases the effort and cost of studying each variation. It may happen that less information is obtained for a greater expenditure of money. By detracting from other scientific studies, the authorization of large demonstration units might actually postpone the day when fresh water can economically be produced from saline water.

I appreciate this opportunity to appear before your committee and would be happy to answer any further questions which are within my competence.

Dr. FOCHTMAN. Mr. Chairman, I have prepared the written statement, so I will just summarize rather briefly what is in this statement and we can carry on from there.

I am with a research organization in Chicago that employs about 250 technical people and does a considerable amount of contract research each year. One of these programs that we did a couple of years ago was for the Office of Saline Water, and that is why I am here today.

This was a relatively modest program involving——

Mr. JONES. Off the record just a minute.

(Discussion off the record.)

Mr. JONES. Go ahead.

Dr. FOCHTMAN. The program that we conducted was rather modest involving only a few man-months of engineering effort. The proposal was originally submitted in April 1955. We conducted a 6-month program during the middle of 1956.

This was entirely a study program, did not involve any experimental work, and was a study of partial pressure distillation, which is a low temperature distillation which will avoid the problem of scale formation.

More recently, we engaged in some studies on the availability of water in various sections of the country and means of alleviating their shortages.

During both of these studies, we found the staff of the Office of Saline Water to be very helpful in supplying all the information they could, technical advice, and so forth.

We have outlined a number of recommendations falling in four general categories: Problem definition, basic research, pilot plants, and methods.

It seems to us in spite of the fact that we have been going for several years here, we still are hazy on our problem definition. In many places, we use this fixed cost figure for water as a goal. Whether this is realistic or not, we are not quite sure. We feel that there are people who can afford to pay more and are willing to pay more than the prices and goals we have set up in the past. Perhaps there should be an effort made to locate these areas, these people, and to promote the processes that we have or almost have at this time in those areas.

The second recommendation concerns basic research. There seems to be a considerable need for this yet, and I believe some of the witnesses have mentioned this, particularly in, say, scale formation and in the electrodialysis equipment.

Pilot plants, I have to defer to other members of the committee or witnesses in that we have had very little experience here in this type of pilot plant. With pilot plants in general, we have had more experience.

The last item of our recommendations concerns methods and there are a couple of things here that, as a research organization, we believe are rather important.

One is for the rather modest program that we undertook, it took a considerable amount of time to get approval of the proposal.

We are not sure why it takes that time, but apparently the proposals are looked over very carefully and examined by a number of people in the field.

We feel that this kind of discourages the research people who originally submitted the idea and maybe have to wait for several months or a year before they can act on the idea. It also discourages an area of research that is what we call blue-sky research, something off the beaten track.

A person may propose a blue-sky idea, but when he knows he has to defend it to maybe 8 or 10 experts in the field, he is less likely to propose this and put it down in writing and to ask for funds to sup-

port this research. We think that a certain amount of research should be blue-sky research in this area, looking for absolutely new ideas.

Another thing in the methods, going back to the original statement, we think there should be a better definition of the problem as far as economic possibilities go, and where we can use the various methods that we have at the moment.

Mr. JONES. Do you mean the method of appraising costs? Is that——

Dr. FOCHTMAN. No, I do not.

Mr. JONES. What do you have specifically in mind when you refer to——

Dr. FOCHTMAN. As you know, there are a number of processes that are used now to make potable water. Some areas in the country, maybe not right at the present but very shortly, would be willing to pay for this water under the present processes that we have, and we feel that there should be some overall picture of where the conversion process fits into the economics.

We favor the pilot plant approach, by the way, that the office is going through now. This area needs considerable technical information yet and we believe the best way to get this would be through the pilot plant approach.

I appreciate the opportunity to be here today.

Mr. JONES. Well, it is good to have you.

Now, I am sure that you were present when we asked Mr. Blohm his opinion about the limitations now in the law restricting the Office of Saline Water for 20 percent for management, and—do you think such restrictions should come out of the law and give the Office of Saline Water more latitude?

Dr. FOCHTMAN. Mr. Chairman, this is a difficult question to answer inasmuch as the continuation of your program means a different amount of appropriations. In some cases 10 percent administrative charges, say in one plant, might be all right; but in another case where there are a number of programs that involve smaller expenditures, 10 percent may be a rather limiting figure.

Mr. JONES. Our chairman, Mr. Dawson, has arrived and Mr. Fascell, member of the committee, is present now.

The witness, Dr. Edward G. Fochtman, of Chicago, is testifying on the question as to whether or not the limitations now in existing law of 20 percent for management should be continued, or whether it should be removed and give the Office of Saline Water wider latitude to make decision in its operating fields.

Dr. FOCHTMAN. Mr. Chairman.

Mr. JONES. Yes.

Dr. FOCHTMAN. I might also point out that the definition of administrative expense and how this is broken down makes considerable difference here, too.

Mr. JONES. Yes, sir.

Dr. FOCHTMAN. I realize the office has several engineers at the moment and some of these engineers must be devoting part of their time to administrative duties and part of it to what I would consider technical duties that should not be part of this 20 percent.

Mr. JONES. Any question?

Mr. INDRITZ. Dr. Fochtman, I have 1 or 2 questions.

Do you think the work, both in pilot plants and perhaps even in commercial plants, in order to acquire production experience, should be emphasized in brackish waters or should it largely be in sea water?

Dr. FOCHTMAN. I cannot give a direct answer to this without a better definition of the problem and the economics involved here.

There are some areas in the country I believe that will want purification methods for brackish water before they are worried about saline water. So until we know more about the needs of the various areas, I do not think that we have an answer to this.

Mr. INDRITZ. Do you believe, therefore, that the definition of the needs will help to stimulate both industry and research groups?

Dr. FOCHTMAN. I certainly do.

Mr. INDRITZ. That is all I have, Mr. Chairman.

Mr. JONES. Mr. Chairman, do you have any questions?

Mr. DAWSON. No.

Mr. JONES. Mr. Fascell?

Mr. FASCELL. No questions, Mr. Chairman.

Mr. JONES. Thank you very much, Dr. Fochtman. It was a pleasure to have you.

Mr. F. A. Loebel, vice president, Cleaver-Brooks Co., Milwaukee, Wis.

We are glad to have you with us this morning, Mr. Loebel.

## STATEMENT OF FRED A. LOEBEL, VICE PRESIDENT, CLEAVER-BROOKS CO., MILWAUKEE, WIS.

Mr. LOEBEL. Thank you. I am pleased to be here.

I attended your hearings yesterday and enjoyed them and I heard the remarks last night expressing your gratification of the quality of some of the witnesses. I just want to take the time out to make an observation from this end of the table, that I am well pleased with these hearings and I think it is a fine thing that you are doing. Communications are so poor all over the world, and I think it is a good thing that you are getting a lot of people together and coordinating a lot of this information.

Mr. JONES. Mr. Loebel, do you want to turn around and make that statement again to the press? They are right there behind you now. Because I recognize you speak with a voice of authority.

You go right ahead, Mr. Loebel.

(The prepared statement of Mr. Loebel follows:)

STATEMENT OF FRED A. LOEBEL, VICE PRESIDENT, CLEAVER-BROOKS CO., MILWAUKEE, WIS.

INTRODUCTION

By way of introduction, my principal duties are concerned with management of engineering for the Cleaver-Brooks Co., manufacturers of packaged boilers, related heating equipment, and saline water evaporating plants. We roughly classify this field as dealing with waters of over 3,500 p. p. m. TDS.

As to the latter subject, it has been my privilege to be in responsible charge of engineering work on sea water evaporating plants for 15 years. In the past decade we have built over a thousand plants for land and marine use, for sea water, brackish water and also purification of fresh water for pharmaceutical uses.

PURPOSE OF THIS STATEMENT

The purpose of this statement is to present to this subcommittee information from our know-how and experience in order to contribute to a fuller understanding of the saline water conversion program. It is well understood from much previous testimony that the main problem is one of cost. It is our intent, therefore, in the following, to discuss the problem of costs as we have experienced it in recent years and as we view the matter from our work on actual proposals, designs, and installations in many parts of the world.

THE PROBLEM

The Saline Water Act of 1952 provided a broad base for research, in that it covered a "* * * practical means for the economical production, from sea or other saline waters, of water suitable for agricultural, industrial, municipal, and other beneficial comsumptive uses and for other purposes." No target cost figures were provided, but early in the program, OSW mentioned in the second annual report goals of $40 per acre-foot for agricultural uses, and $125 for industrial uses. It was evidently recognized that the matter of setting cost objectives was a vital one in plotting the course of the research program. With figures set too low, there would be a tendency to overlook possible improvement to existing processes, and set too high, there would obviously be discouragement in conducting research for certain uses.

We believe that not enough attention has been given to what the target figures should be, and that further study should be made to set goals that seem to be attainable in the light of present knowledge, and in the light of further improvements which can now be envisioned with a fair degree of certainty.

WHAT SHOULD WATER COST?

Regarding the price of water generally, there is, perhaps, no other commodity which sells at such a wide variation in price. In the city of Milwaukee, municipal water costs about 21 cents per thousand gallons, or about $70 per acre-foot. At the other extreme, we have various bottled waters from 15 cents to about $1 per gallon, or $50,000 to $325,000 per acre-foot, and water suitable for medical purposes in small containers (ordinary distilled water, but sterile, pyrogen free) which comes to $10 million per acre-foot. The costs of other municipal and suburban waters are well known, and prices which range to about $200 per acre-foot are not uncommon. In Nassau, well water sells for about 80 cents per thousand gallons, or about $260 per acre-foot. About 60 percent of this is represented by cost of production at the wells and storage.

It should be kept in mind that the municipal and suburban costs relate to water found in either surface or underground supplies. These waters have not been processed in any type of plant, except, perhaps, by softening, filtering, or chlorination, but are merely distributed by means of pumps or pipelines.

Let us assume for the time being that water can be made now in large plants for about $1 per thousand gallons, when all costs are included. A thousand gallons of water weighs a little over 4 tons. We would, therefore, have a price of about 25 cents per ton. We have found no common material that seems to approach this cost. Common salt is about $15 per ton, and limestone about $2 per ton. Even ordinary dirt fill often costs over 25 cents per ton delivered, so we can truthfully say, if our dollar-per-thousand figure is correct, that today distilled water can be manufactured from sea water at a cost "which is cheaper than dirt."

There are two other important considerations that have a bearing in arriving at a proper perspective as to what water should cost. For one thing, figures of $40 and $125 per acre-foot are essentially prices concerned with water that is given to us free by nature. This natural process employs fuel which is free, and the process is moreover carried on in natural surroundings which are also free. As soon as we try to confine this natural water in even the simplest kind of equipment, such as pipelines and pumps, we immediately incur substantial costs.

Other than being free, the natural process is a very inefficient one, since it is only a single effect evaporator. If we were to duplicate this process in a plant, the manufactured costs would be many times the figure of $1 per thousand gallons.

### ABOUT SOME EXISTING PROCESSES

Regarding existing processes, we have always employed evaporating means for conversion, although our policy has never limited us to this, and we have always sought a more economical method regardless of the process it might be. To date, however, we have found no way to supplant evaporation, which we classify in three main types:

*1. Submerged tube*

There are some plants of this old and widely used design in operation on sea water which are among the most successful installations from a mechanical standpoint. We believe, however, that some basic limitations to this system have been indicated in sufficiently definite form to strongly suggest that the present trend to other types will continue.

*2. Vapor compression*

Where the raw water can be readily treated by softening, this is, perhaps, the most favorable method known today. It is usually used for sea water evaporating jobs which fall within these approximate limits:

(*a*) Relatively small plants, up to, say, 200,000 gallons per day.
(*b*) Fuel difficult to procure or relatively expensive.
(*c*) Good maintenance facilities available.

Keeping in mind that this type is highly efficient and compact, it is ideal for many military uses, which are usually within the above limits.

This process has too many limitations to be considered for large-scale seawater plants now. Future improvements may make it far more favorable, if not one of the best ultimate answers. The low energy requirement is attractive where primary energy must be used as compared with waste heat.

Although the first cost would be high, it is interesting to contemplate that by using enough heating surface and an efficient compressor, a machine using this process could be built today which would come closer to the theoretical 2.8 kilowatt-hours per thousand gallons of pure water from sea water than any other available process.

*3. Multistage flash*

In recent years, our efforts in research, design, and manufacturing have been mainly concentrated on the low-temperature, multistage, flash evaporator for marine- and land-based applications. We still offer vapor compression and submerged-tube types, but the flash evaporator is more widely applicable for the following reasons, given in their order of importance:

(*a*) It operates substantially without scale. For normal sea water, no feed treatment is required if the once-through type of principle is used and temperatures kept low.
(*b*) It is simple to operate and maintain. There are few controls and moving parts.
(*c*) It can use a relatively low-level heat source.
(*d*) First cost is favorable.

It follows that this type is a good choice when waste heat can be used, as, for example, for diesel engines. When combined with a powerplant, using steam from condensing-extraction turbines, the cost of water is in the order of about $1 per thousand gallons, using OSW standard cost procedure. While this cost is far from favorable for agricultural purposes, costs more than double this are now being tolerated for domestic and certain industrial uses, which is to say that this figure seems to be at least somewhere near the target area.

### ESTIMATED COSTS OF SOME EXISTING PROCESSES

The combination of multieffect or multistage flash plants with electric powerplants has gained favor in recent years. A few plants of this type have been installed, and others are now being considered. This type of arrangement results in one of the most economical ways of converting sea water.

The amount of water that can be obtained from a steam powerplant by using extraction steam from the turbine for heating the evaporator will vary somewhat, depending on many factors. A figure of 7½ gallons per kilowatt-hour, however, has worked out in a number of instances. Taking an electrical consumption of 8 kilowatt-hours per person per day, we see that the water production in this way would be 60 gallons per person per day.

In the United States, the consumption per capita for all uses is about 1,000 gallons per person per day. For municipal and rural use, it is about 100 gallons per person per day. With some attention to conservation, the 60-gallon figure is quite adequate. The monthly water bill at, say, $1.20 per thousand gallons, including distribution, would be $2.15 per person, which does not seem unreasonable. In such a community, agriculture could not exist unless water could be obtained in some other way, by reuse, reclamation, other sources not suitable for human use, etc.

For a number of current projects, costs for a combined plant have been figured by considering the water as a byproduct of electric power. This seems logical, and has been acceptable to a number of power companies, since electric power is able to stand on its own feet, whereas water is, generally, not.

When a water plant is added to a powerplant, the turbine takes more steam and the boilers must be larger. The customary way to figure cost of water is, therefore, to charge the water plant for all additional costs which the powerplant incurs, as compared to operating alone with conventional generating and condensing equipment.

A set of cost figures for a million-gallon-per-day plant, combined with about 5,500 kilowatts electric load, is shown in the table below:

*Costs for a 1,000,000-gallon-per-day (net output) sea-water distilling plant*

| | A | B | C |
|---|---|---|---|
| 1. Investment | $1,534,900.00 | $1,240,000.00 | $1,960,000.00 |
| 2. Working capital | 61,000.00 | 55,000.00 | 95,000.00 |
| 3. Operating costs (per day): | | | |
| Fuel and power | 550.00 | 550.00 | 540.00 |
| Amortization | 300.00 | 250.00 | 395.00 |
| Other | 165.00 | 150.00 | 610.00 |
| Total | 1,015.00 | 950.00 | 1,545.00 |
| 4. Cost per 1,000 gallons | 1.02 | .95 | 1.55 |

All costs are included as in OSW standardized procedure,[1] except as modified where firm price and design information is available.

Column A represents a multistage flash plant heated by steam at atmospheric pressure from a 6,000-kilowatt extraction-condensing turbine. Steam to turbine at 600 pounds per square inch gage and 825° FTT. Fuel at 8.5 cents per gallon. Steel construction with nonferrous tubes and tube sheets.

It can be seen from column A that, even if amortization is completely eliminated, we still have a cost of about 70 cents per thousand gallons. Even much larger plants do not seem to reduce the cost figure by a very large amount. For example, if only the basic material is included, thus eliminating all costs for transportation, labor, overhead, and profit, the cost of water, using the means described above, would be reduced only about 15 cents per thousand gallons.

The costs apply to a multistage plant, which is fairly efficient, about 5½–6 pounds of water per pound of steam. The plant could be made more efficient, but cost studies show that, for the conditions upon which the costs are based, the carrying charges for more investment would outweigh the fuel saving.

Column B is for a similar combined plant, but includes foreseeable future improvements in design and manufacture.

Column C is for a vapor-compression plant. At joint hearings on water supply in 1951, we submitted a $1.12-per-thousand-gallon figure for a vapor-compression plant. Column C is, therefore, largely intended for reference, and brings the costs up to date with regard to present-day labor and material prices.

### THE CURRENT STATE OF PROGRESS

Despite the seemingly high costs reported above, when compared with our everyday concept of water cost, we believe that progress has been good with regard to plants for domestic and some industrial uses. During the past decade, the

[1] This procedure is quite complete. Investment includes transportation, insurance, erection, water storage, interest on capital during construction, engineering, contingencies, and site. Annual costs include 20-year (4-percent) amortization, 4-percent interest on investment and working capital, all maintenance, labor, supplies, fuel, power, taxes, insurance, G. and A., etc.

installed sea-water distilling-plant capacity throughout the world has grown substantially. In rough figures, from about 1 million gallons per day plant capacity in 1948 to about 12 million gallons per day today, not including small plants below, say, 50,000 gallons per day.

Concerning the conversion of sea water for agricultural use, it is evident that the progress has been disappointing. There appears to be no factual evidence today which suggests surety that a price appreciably below $100 per acre-foot, if all costs are considered, will ever be attained. There is, moreover, room for doubt that a figure this low can be attained with any process now known, when using OSW cost procedures. The figures herein suggest a minimum somewhere around 70 cents per thousand gallons.

### FUTURE RESEARCH AND DEVELOPMENT

With regard to reduction of costs in the future, it is difficult to visualize a cost as low as 50 cents per thousand gallons in any type of a process which must be confined in a plant, such as in an evaporating plant, electrolytic cells, or other devices. In Milwaukee, for example, water is obtained very simply by pumping it out of Lake Michigan, followed by filtration. Selling price is about $70 per acre-foot. Let us imagine a hypothetical sea-water conversion plant and assume that this cost, at least, would be incurred for pumping.

In addition, power or heat is required to separate the salts from the water. This figure is, theoretically, 2.8 kilowatt-hours per 1,000 gallons. Present processes are about 3 to 5 percent efficient. If we ultimately have a process that is 20-percent efficient, we would need about 14 kilowatt-hours per thousand gallons for separation only. At 7 mills per killowatt-hour this would be about $30 per acre-foot.

Then, as to the process itself, let us further assume that it would be as simple and economical as pumping out of Lake Michigan and filtering, or an additional $70 per acre-foot. Totaling the above, we have a cost of $170 per acre-foot, or about 50 cents per thousand gallons, which would seem to be about the minimum for a confined process.

For costs lower than this, it would seem that the process must ultimately be one where some free natural energy and facilities can be largely employed. Cloud seeding would be one such process. Another might be in the biological field, the separation being accomplished by plant or animal life.

The problem of reducing costs of sea-water conversion can be roughly divided in two parts. First of all there is the matter of improving processes already in commercial use. A manufacturer does not always have funds available to try out all promising modifications or variations of existing processes. Also, a manufacturer does not have funds to set up a fairly large plant for demonstration and cost study at, say, some water-short seaboard community. The Federal Government could, perhaps, help in this respect, but we believe any work should be initiated through negotiation with manufacturers experienced in the field.

The second part of the problem lies in basic research, and if funds are limited, we believe the Government should concentrate on this aspect.

Concerning cost estimates, conversion data, etc., there are so many conflicting and misleading statements in the press and in the literature, that this matter should be cleared up. There are many ways of attacking this problem, but at the moment we rather favor the construction by the Federal Government of a fairly large plant for demonstration. Perhaps, this should be along the lines of a design contest with manufacturers submitting their own ideas, guarantees, and firm prices for a plant of, say, 1 million gallons per day, which should be a large enough plant to establish costs. All appropriate cost criteria, such as amortization, fuel cost, etc., to be stipulated by the Government.

Mr. LOEBEL. To introduce myself, I am in charge of engineering for the Cleaver-Brooks Co. We are boiler manufacturers and manufacturers of saline water evaporating equipment.

I want to put a limitation on the saline waters as we know them and as I am going to discuss them, and that is in the range of 3,500 parts per million up to sea water of 34,000 parts and beyond when required.

It has been my privilege to be in this field for about 15 years in addition to boiler business. And, again merely by way of introduc-

tion, we have been quite active during the past decade and have installed about 1,000 plants of various types, including brackish, including waters that are fairly fresh, and fresh waters for pharmaceutical purposes.

The purpose of my statement is to add what I can to the understanding of this saline-water project and problem from a standpoint of cost, which is well understood as being about the main problem. I want to try and contribute what I can from our own experience as we have encountered this cost problem in actual work and designs and actual installations.

In research work generally, one of the most important things is to define the problem. I do not infer that is the case here, but often you find when you define the problem really well, you find there is no problem at all.

Again I do not intend to infer that in this case, but it is important to define it.

The Saline Water Act of 1952 covered a very broad area. It covered agricultural water all the way to beneficial consumptive uses. That includes everything I guess.

The thing they did not define was the goal. The Office of Saline Water recognized the importance of this and in their 1952 report, they set goals of $40 an acre-foot for agricultural water and realizing that industrial water could be somewhat higher, they set $125 an acre-foot for that.

Setting the figure is very important. If you set it too high, you discourage research for certain uses; and if you set it too low, you discourage research in improving what you already have.

We feel that more study should be given to this goal and try to set it a little more realistically in the light of what we think is attainable in the near future.

In thinking of that, I tried to come up with some idea as to what water should cost, and I asked that question. Although I do not provide an answer, I am presenting some information here and perhaps you will come to your own conclusions.

I got on the phone just before I came down here and I called the Milwaukee Water Department. My figures here are pretty local but nevertheless they are real figures.

In Milwaukee, we get water very easily out of Lake Michigan. It is hard to visualize any easier way to get it except in the rain barrel. It is $70 an acre-foot, 21 cents a thousand gallons.

At that price, that is one of the lower ones in the country, and still—as a matter of fact, the water department does not feel that they can add to their plant and expand it, as they really should, at this figure.

Mr. JONES. You have a byproduct there in Milwaukee that you sell. That means you have cheap water. Go ahead.

Mr. LOEBEL. It is cheaper than some water. Well, it is $70; recently it went up 50 percent and it probably will go up some more. Now, at the other extreme, I wonder just how costly some water could get.

You are all familiar with paying about 15 cents a gallon for water; that is $50,000 an acre-foot. I have paid $1 a gallon and that is not rare, which is $325,000 an acre-foot.

The pharmaceutical field—it has been one of our specialties, and I called the medical supply house and asked them what they wanted for intravenous water which comes out of the compression still probably. It does not mean it costs this much, but anyway the price comes out to $10 million an acre-foot.

So getting back to suburban and municipal waters, $200 an acre-foot is very common in the country. In Nassau, it is pumped out of wells, and that is about $280 an acre-foot.

One thing you should keep in mind is that these municipal and suburban waters are natural supplies and surface and subsurface supplies, and nothing has been done to them except perhaps filtering and chlorination.

We have heard a magical figure a number of times, $1 a thousand gallons. I am using that in my illustration for the time being. Let's see what that means.

Let's assume we could make water for $1 a thousand gallons, and that is not including distribution. That is about 4 tons of water and that comes out to a little under 25 cents a ton.

I tried to find some manufacturer of a commercial commodity that was that cheap and I was not able to think of any.

Common salt is about $15 per ton and limestone is about $2 a ton. And I recall when I built my home, it cost me about 30 cents a ton to have the fill taken away; and when I wanted some more, it cost about the same price to get it back. So I say that at $1 a thousand gallons, you can make water today that is "cheaper than dirt."

Now, another couple of considerations in setting the price of water, these figures of $40 and $125 are water that is obtained in a natural process, by nature. The "fuel" is free and the container that the water is in is free, the subsurface storage, lakes, and rivers and valleys, and things of that nature.

So now, as soon as you try to confine any process into any kind of steel equipment, or what have you, pipe lines or pumps, you add substantially to the cost.

Just as a matter of interest, the natural process is very efficient. It is a single evaporator, which is almost never used in industry.

I will touch briefly on these existing processes. They are in the record I understand.

I touched on submerged tube evaporator, which seems to be being supplanted by other types.

Vapor compression, we feel is not ready for large plants, but it has a very interesting property. We feel that it could perhaps come closest to the theoretical 2.8 kilowatt-hours per thousand gallons than any process known today.

Of more importance we think today is the multistage flash evaporator, and our main efforts have been on that the past 4 or 5 years. It has certain advantages, and I want to make a particular point about this; it operates substantially without scale and will operate substantially without scale, without feed treatment of any kind, if you have a once-through principle and you keep your temperatures low. The Navy specs, as a matter of fact, require 3 months' operation without cleaning and 6 months is not an unusual thing. It is simple. It uses a low-level heat source. Its first cost is good and it works really well in combination with electric powerplants.

This system, by the way, has gained importance in recent years. A number of plants are contracted for now. Most large proposals that we are familiar with that are up now are for the combined type of plant and also with the flash evaporator.

The combination with the powerplant is not bad with regard to water supply either. The figure of how much water you can get is subject to some variation, but 7.5 gallons per kilowatt-hour is a fairly good figure. And taking 8 kilowatt-hours' consumption per person per day, you come up with about 60 gallons an hour, which with some contention to conversion is a good figure. You can live well on that. You do not have a showerhead this big [indicating], and you do not sprinkle your lawn at all perhaps, but anyway you can have a good community on that basis, and you can even have some air conditioning.

Well, the water built in for 60 gallons a day per person at $1 a thousand gallons, adding another 20 cents for distribution, would be $2.15 a month per person, which does not seem to be an unreasonable figure.

You are not going to have any agriculture, you are not going to be growing corn in Arizona, but anyway this is what you can do today if the dollar figure is correct.

Now in giving the cost of that plant—and we have some costs here, they are estimates to be sure, but nevertheless they are based on actual detail designs, designs of plant. But the estimates, of course, have to do with the storage facilities, the labor maintenance; and in that light they are estimates.

I have prepared a table; and I particularly kept it simple, although the actual breakdown is very detailed. These figures are based on water being a byproduct of electricity because an electric plant can economically stand on its own feet and a water plant can generally not.

These figures also include the additional cost charged to the water plant for larger boiler, larger turbine, extraction condensing turbine, and also the incremental costs per day that the powerplant incurs as a result of the water plant. In other words, it burns more fuel and it has a bit more labor, and all those costs are in this figure. Although I want to point out that these costs are not pessimistic, they are not pessimistic, you still have a fairly sharp pencil and I come out to $1.02 a thousand gallons, broken up into the fuel at 55 cents and amortization and other costs, 47 cents.

These were figured according to OSW procedure, which we think is quite complete, and we think it is quite realistic in many respects.

It includes such things as your interest on your capital during construction, distillate storage, and they are all listed in the paper here. But you will find them very complete and real costs for plants built in this country.

Now, I played around with these figures to see what the costs get down to and remembering that amortization was 30 cents of the $1.02, I said let's take all that out. That still only gets us down to 70 cents a thousand gallons.

This was a 1-million-gallons-a-day plant so I said let's see what a larger plant might cost. Your heating surface and all has got to stay about the same, but you will save some in labor in building the plant. So I said, well, we will take out all the labor and profit and overhead, out of the plant cost, and that only saved about 15 cents a thousand gallons.

On efficiency, the plant figure 5½ to 6 cents per pound of water, pound of steam. It could easily be made more efficient, but for the particular conditions we assumed 8½ cents a gallon for fuel. It came out the additional investment would not be outweighed by the fuel saving.

There is another column in there which envisions improvements that we could foresee which takes another 7 cents off of the $1.02 figure.

Column C is a vapor-compression plant and was put in for the record to bring our 1957 figures up to date with modern material and labor costs.

Now, this all might seem somewhat discouraging in one way; when you think of the water bill of $2.15 a person, it is encouraging, I think. At any rate for industrial and domestic use, we think progress has been really good.

The world capacity has gone up about twelvefold since 1948, from 1 million to 12 million gallons a day.

Now, as to the $100 per acre-foot figure, we know of no factual evidence that suggests that figure will ever be beat at any time and there seems to be considerable room for doubt that any known process we have today would get down to that figure; the figures that we submit here come out to about—they suggest about 70 cents.

Now, as to progress. We think the Office of Saline Water has done a very creditable job considering the magnitude of the problem and whatever limitations they have on their administration, and by the law.

With regard to the future, I tried to find out what might be the ultimate in setting the goal, what might be done; and because we find it hard to conceive of the 50-cents-a-thousand-gallon figure in any kind of plant, in any kind of plant that would confine a process like an electrolytic cell.

So in a very crude way, I said let's assume that we have to at least distribute the water, and I took the Milwaukee figure of $70 per acre-foot and then I said, "Let's take the theoretical figure of 2.8 kilowatts a thousand gallons, which it takes to separate the water from the salt." And our present processes are around 3 to 5 percent efficient.

I said let's assume we have one that is 20 percent. That would mean 14 kilowatts and at 7 mills a kilowatt-hour, it would mean another $30.

Now we do not have a process yet, so I said let's assume we have a process that is as good as dipping it out of Lake Michigan. That would be another $70. So we totaled $170 an acre-foot, or 50 cents a thousand gallons.

It would seem from this that whatever process ultimately gets down to this cost would be somewhere where the energy would be free and the container would be free, like cloud seeding.

I mention that only as an example, perhaps an impractical one, but anyway it is what I have in mind. Or biological means, and there have been some suggested areas in that field.

Now, as we visualize the future, there are two problems. One is improving what we have, and the other one is fundamental research on just such things as this, perhaps cloud seeding or perhaps something else that somebody might envision.

So as far as the Government is concerned, we think if their funds are going to be limited, we would like to see them stick with the basic research, and in the "blue sky" area; that says it very well.

However, on the cost, there is so much confusion on that today and we do not think there should be that much. We think it would be a good thing if the Government would have a large plant built somewhere and see what these costs might be.

We think that a million gallons a day would be plenty large. We think it should be along the lines of bids from manufacturers experienced in the sea-water field. Even today you can get firm bids and guaranties as to performance on a million-gallon-a-day plant.

Now, it was mentioned earlier that even when you built a plant, you still have arguments about costs, and that is true. Nevertheless, in an example Dr. Schroeder brought up in talking about what a barrel of oil cost, you at least know it is not 50 cents and you know it is not $5. But in the previous testimony last year, we had figures all the way from zero on up. And that is too wide a spread.

We think that a demonstration plant should certainly peg it a little closer than that.

Now, nobody said anything about conservation and if our figures are right here, it might be sometime before we get down to a figure where we would have anything that agriculture could afford to pay. So we think something should be done about conservation now. And just what lines that might take is, of course, a huge subject. But there is a lot that could be done in conserving our supplies now. We are very wasteful with water. I think that about concludes my remarks, Mr. Chairman.

Mr. JONES. Thank you, Mr. Loebel.

Mr. Chairman?

Mr. DAWSON. No.

Mr. JONES. Mr. Fascell?

Mr. FASCELL. Yes; I would like to ask, "What are the priorities on the uses of water?"

Mr. LOEBEL. The priorities?

Mr. FASCELL. In this country.

Mr. LOEBEL. I mean, as to industrial, agricultural, and human?

Mr. FASCELL. Yes.

Mr. LOEBEL. I have no idea. Of course you would have to live first and you have to have water to live, but that is strictly a philosophical way of looking at it. I do not know who is the shortest of water.

Mr. FASCELL. I was just wondering, would not the point of greater sale determine the first place you would do any research?

Mr. LOEBEL. Well, perhaps in talking about where you might put such a demonstrating plant; yes.

Mr. FASCELL. I mean you would not sell soap to cows.

Mr. LOEBEL. No, sir. No, sir.

Mr. FASCELL. That is what I had in mind.

Mr. LOEBEL. I think you would put it somewhere where you had a sale of a byproduct: yes. Some town—well, I think if I understand you correctly, like California, for example. I think they have been short of water there for many years. It might be a good place.

Mr. JONES. Off the record.

(Discussion off the record.)

Mr. JONES. Each member of the committee will be supplied with a copy of those Geological Survey water supply studies [indicating]. I thought they would be of great interest, Mr. Chairman, to the mem-

bers of the committee because it breaks it down to their own areas and defines it in the light of their own district needs.

Mr. FASCELL. Of course, what I have in the back of my mind, Mr. Chairman, is why need would not determine cost ultimately.

Mr. JONES. I think we have had some good——

Mr. LOEBEL. I think I tried to establish that because I think it is true that you can have a community, without agriculture, with what can be done today. But $1 a thousand gallons per head—let's assume that is pretty near right—is not bad. You can have a community, you do not have to have a real wealthy community to sustain that.

Mr. FASCELL. But you could not compete with Milwaukee that has Lake Michigan?

Mr. LOEBEL. No; you could not.

Mr. JONES. Because Chicago cannot get any of Milwaukee's water on a diversion, so that shows you even they need it in Chicago, although you have a whole lake there.

Mr. FASCELL. I was just wondering whether or not this is not one of the factors that must be considered in this problem. In other words, if you are shooting at a competitive price nationwide, that is one approach. I do not know whether that is the right approach.

Mr. LOEBEL. I think your illustration brings out the point that it is necessary to set some goals. They might not be the same goals for everyone. If you are going to shoot for $40 an acre-foot, it would be a long time before Florida would get any water made through a mechanical process.

Mr. FASCELL. Well, I got lost here somewhere in this discussion, because what I am trying to get clear in my own mind is the necessity for establishing, in advance, a cost factor.

Mr. LOEBEL. Oh. Well——

Mr. FASCELL. I mean, if I think I am going to sell automoblies, then my job is to get an automobile that will sell. Now, it might be incidental or necessary, before I do this, to analyze my market, my costs, and see whether or not I am going to be in a competitive position.

Mr. LOEBEL. Well, of course if you were going to have a research program and you were going to set a cost of say $40 an acre-foot, I think it would be immediately apparent that you would not be interested in any existing process at all. Do you see my point?

Mr. FASCELL. Could not sell any then?

Mr. LOEBEL. You could not reach your objective in that manner. Your sights might be set way too high. We weigh everything against agricultural cost is what I am trying to say. I do not think that is proper. We are weighing what we are trying to do experimentally against what is done for us free in nature, and I do not think it is a fair comparison.

Mr. FASCELL. I certainly agree with that logic.

Mr. LOEBEL. Well——

Mr. FASCELL. Is there any confusion on objective in what we are trying to do?

Mr. LOEBEL. I think there is, because you often hear it said in the literature and the press that distilled water is very expensive. It's a tremendously expensive thing and I have tried to show there are many cases where it is not. It is actually cheap. And for that reason I think that the objectives have been set—let's put it bluntly and

say to almost an impossible goal to get what we get free out of nature. And some of the other things have been somewhat overlooked because in the meantime in other parts of the world, plants have been and are being put in and people are living and existing. And this could be done here. It could be done today.

Mr. FASCELL. I want to thank you because that does clarify your position for me.

Mr. LOEBEL. Well, I am glad then.

Mr. FASCELL. That's all I have, Mr. Chairman.

Mr. JONES. Mr. Chairman?

Mr. DAWSON. No.

Mr. JONES. One proposition in your statement that interested me is the suggestion of design contests with manufacturers. Would you like to elaborate a little further on that?

Mr. LOEBEL. Yes; I think that, judging from activities in other parts of the world, large plants are being built today, and manufacturers' experience is that sea-water fields do not always have the same idea as to the best way it should be done. And, in a contest that I mention there, I have in mind that the way would be left open for manufacturers to come in with their own ideas as to how it could best be done with the designs they would recommend at a fixed price and back up with guaranties. The Government, however, setting down the——

Mr. JONES. Do you think that would stimulate greater interest in designs of plants?

Mr. LOEBEL. Well, you'd have one bidder. But I think it's important that the Government would set down what——

Mr. JONES. You're enthusiastic, Mr. Loebel. I believe you'd be with us whether we had a contest or not. But do you think that would stimulate——

Mr. LOEBEL. Yes; I do.

Mr. JONES. Have you had very much contact with the Office of Saline Water?

Mr. LOEBEL. Yes; we call on them from time to time. We try to keep up with their program.

Mr. JONES. And have your contacts with that agency been satisfactory?

Mr. LOEBEL. Yes; it has been satisfactory. We haven't had any contracts with them. We haven't had——

Mr. JONES. Do you have any suggestion as to how we could improve the law to make their work more fruitful?

Mr. LOEBEL. Yes. I believe that that administration limitation should be removed, and also the limitation on basic research. I think that this should be left up to the manager of the department and that if and when indicated that one or the other should be increased, he is free to do so, even up to the extent of having 80 or 90 percent basic research. I don't think there ought to be any limitation on that.

Mr. JONES. Thank you very much. We appreciate your coming, Mr. Loebel.

Mr. W. A. Morey, vice president (engineering) of the Whiting Corp., of Harvey, Ill.

We are glad to have you, Mr. Morey.

## STATEMENT OF W. A. MOREY, VICE PRESIDENT (ENGINEERING), WHITING CORP., HARVEY, ILL.

Mr. MOREY. Thank you.

Mr. JONES. Now, Mr. Morey, we had planned to have all the statements put in the record, and we are going to let you summarize your statement and make your observations.

Mr. MOREY. Thank you.

(The prepared statement of Mr. Morey follows:)

STATEMENT OF W. A. MOREY, VICE PRESIDENT (ENGINEERING), WHITING CORP., HARVEY, ILL.

The widespread recognition of potential fresh-water shortages in the United States and elsewhere in the world render unnecessary any extended comments on this general subject other than perhaps to note that many of the water-short areas, both in the United States and in the world, are situated close to inexhaustible supplies of ocean water. Thus, the problem of treating salt water is in itself a segment of the more generic problem of fresh-water resources and in turn divides itself logically into the treatment of ocean water and the treatment of salt waters other than ocean water, the latter generally having a far lower total solids content.

For the past several years the Department of the Interior, under the authority of Congress, has investigated both portions of this specific problem and has carried on a number of development activities in this regard.

With the possible exception of air itself mankind has no more fundamental need than potable water. The effect of insufficient fresh-water supplies upon the economy of large areas requires only a moment's reflection and appears reasonably well illustrated by the coastal areas along the southern portion of the Mediterranean. It would be difficult to imagine any more valuable development to such areas than some means for providing fresh water from the sea at a reasonable cost. Ironically perhaps, a substantial portion of this area has easily available petroleum fuel in copious volume for the operation of water beneficiation projects. Other segments of this coastal area are perhaps not as fortunately situated with regard to petroleum fuels but are well supplied (or perhaps over supplied) with solar energy which may supply the necessary heat if an economical means can be evolved for its utilization. The relations between these countries and the United States would probably not be injured should this country assume the lead in providing a feasible process for supplementing the potable water supplies of these areas.

In our own country there appears to be many coastal areas whose growth potential is limited primarily by the cost and availability of fresh water. Other more fortunately situated coastal areas have sufficient reserves of fresh water under normal conditions but have foreseen the incalculable damage which could be inflicted on the economy of an area by prolonged shortage of fresh water due to drought or other causes currently beyond our control and may seriously consider treatment of sea water to supplement normal supplies. It seems clear therefore that a satisfactory solution to the problem is of importance to many areas in the United States as well as in foreign countries and could have a favorable effect on foreign relations.

Considering the scope of the problem, it is sometimes difficult to remember that man has known for many years a method for producing fresh water from ocean water. A simple still with a condenser is all that is required. The problem then is not merely to produce fresh water but to produce fresh water at a cost sufficiently low to fit into the economy of a given area. The Department of the Interior in its saline water conversion program recognized this all important fact and quite properly initiated its program by a widespread study and investigation of every possible process for treating salt water which might lead to a satisfactory answer. Some of the more unique proposals seemed bizarre and others promising while still others represented refinements in varying degrees to older and well recognized processes. The annual reports of this office show that investigation has been carried on with respect to various forms of electrical separation procedures with and without the use of membranes, the various forms of solar distillation, critical pressure distillation, purification by the application

of osmotic pressure, solvent extraction of impurities and freezing. The most competent investigators available, many of them at our universities, have been engaged by the Department to study and report on the possibilities of these various processes. As might be expected, many of the proposals have been rejected after preliminary investigation as not offering sufficient promise. Others appearing to offer promise have been made the subject of more extensive investigation. Since the reports of these investigations have been published and distributed, detailed comment or enumeration is considered unnecessary.

The Whiting Corp., through its wholly owned subsidiary, Swenson Evaporator Co., has been cooperating with the Office of Saline Water Conversion in the study of a multiple-effect distillation process. This testimony is therefore confined primarily to this project.

Since much of the testimony is necessarily opinion, it is perhaps of interest to this committee to know something more of the company involved and its background. The Swenson Evaporator Co. is one of the oldest, if not the oldest, companies in the United States dealing primarily in the design and fabrication of evaporators. It has been in business since 1893 and was purchased by the Whiting Corp. in 1922. In its more than 60 years of existence, the general type of business has been maintained but increased in scope through the addition of other products such as crystallizers, spray dryers, and allied chemical process equipment. About 1932 the Swenson Evaporator Co. designed and fabricated a then new type of evaporator for a Wisconsin paper mill. This evaporator, known as a long tube vertical evaporator, proved to be very highly effective in this application not only because of satisfactory process operation and low maintenance but also because the cost of operation was remarkably low compared to other forms of evaporators. A great many of these evaporators have since been designed and installed in paper mills throughout the United States and Canada. Many of them reach substantial proportions. One of these installations in the South for example, which has been in operation for a number of years, has an evaporation rate of 500,000 pounds of water per hour and even larger units are currently in the process of fabrication. The continued use of these evaporator systems by the paper industry is convincing proof of their economy of operation.

The present form of evaporator represents a considerable advance over the earlier units due to an extended program of research and development. For many years the Swenson Evaporator Co. carried on a continuous program of development with the University of Michigan during which time many discoveries of fundamental importance in the evaporator field were made. This work at the university was directed by Dr. W. L. Badger, then a professor of chemical engineering at the university and a recognized leader in his field. Dr. Badger has subsequently retired from the University of Michigan and has entered consulting practice with the Swenson Evaporator Co. as one of his clients. He has continued in this capacity for many years and is currently also both a consultant and subcontractor to the Office of Saline Water Conversion.

In the very early studies of salt-water benefication some preliminary estimates were made of the cost of evaporation. These estimates indicated that the process was not particularly appealing due to its relatively high cost and that it missed meeting the target prices established by the Office of Saline Water Conversion by a considerable margin. This matter came to the attention of Dr. Badger and Swenson Evaporator Co., both of whom possessed detailed current knowledge of evaporator costs due to their continuous activity for many decades in this specific area of activity. A review of the problem and a preliminary cost study demonstrated quite conclusively that the estimated costs were unrealistically high. A tentative flowsheet was then prepared together with preliminary cost estimates and presented to the Office of Saline Water Conversion. These costs were such as to indicate the reasonable probability of closely approximating the target price of $100 per acre-foot for water intended for human consumption.

Everyone concerned realized quickly that this proposal did not represent a flight of scientific fancy into the unknown but rather that it was a modification of equipment systems currently in widespread industrial use. Dr. Badger was therefore requested to prepare and submit a more detailed report including flowsheets and an analysis of operating costs as well as engineering considerations.

The unit was visualized as a series of 10 evaporator bodies, technically known as a dectuple-effect evaporator. The cost analysis indicated that under favorable circumstances such a unit might be expected to produce fresh water from ocean

water at a price of approximately $0.35 per 1,000 gallons or about $100 per acre-foot. The long and successful industrial history of this type of evaporator installation removed many of the doubts inevitably raised with regard to other proposals. For example, the costs of closely related industrial operations were available for comparison and the comparison could be carried out by engineers having years of experience in this field. There was little doubt as to whether the unit would operate.

Furthermore, the number of questions which would have to be answered before the construction of a plant could be considered were reduced to a minimum. Thus, on paper at least, this process seemed to offer a highly feasible approach to the problem and a good chance of obtaining very pure water at target costs with a minimum of risk.

It might be well to note at this point that multiple-effect evaporation can be applied to either mildly brackish water with a relatively low content of solids or to ocean water with its exceptionally high solids content. This is not true of many of the other processes given serious consideration by the Office of Saline Water Conversion. There are other processes apparently under investigation which offer considerable promise in the treatment of mildly brackish water, such as those found in large underground reservoirs in the western portion of this country. Such processes however do not appear at this time to offer great promise in the treatment of ocean water.

It should not be assumed that multiple-effect evaporation constituted a clear and decisive answer to the problem however. As Dr. Badger clearly stated in his earliest report, the cost figures were predicated on the use of some procedure which would keep the tubes of the evaporator free from scale. Some of you are undoubtedly familiar with the difficulties experienced in the operation of boilers on hard water. As the water is evaporated, some of the solids ordinarily dissolved in the water are precipitated and deposited in rocklike form on the walls of the tube carrying the water. This deposit greatly reduces the rate at which heat can be made to flow through the tube into the water, and in extreme instances may completely plug the tube preventing even the slow circulation of water. Therefore, scale must be eliminated or at least minimized if successful operation is contemplated.

The problem of scale formation is not of recent origin. The Armed Forces and the Navy in particular have devoted much time and effort to the study of the scale-prevention phenomena, the same being true of many companies and universities throughout the world. Over a period of years substantial progress has been made in eliminating this undesired characteristic. The applicability of the various solutions proposed varies considerably according to the desired objective and the characteristics of the process under consideration and differs at least in degree between boiler operation where condensate is returned to the system and evaporator operation where condensate return is not desired.

Again the Office of Saline Water Conversion recognized the fundamental importance of this problem from the outset and studied the proposed solutions with considerable care. Since certain of these appeared to have direct application, Dr. Badger's proposal for construction of a pilot plant to test these processes was approved. This proposal called for the construction of a test evaporator installation in an area having access to ocean water and of a size sufficient to yield reliable test information. Whiting Corp. reviewed this proposal and advised the Department of the Interior that in their opinion the application of multiple-effect evaporation to the problem was proper and that the procedures proposed for the prevention of scale had good prospects of success.

A number of conferences then occurred, principally with Mr. David Jenkins, Director of the Office of Saline Water Conversion, relative to the design of the test installation, its operation and other pertinent matters. It was during this period of intensive review and study that Whiting Corp. realized not only the importance and scope of the program but also the implications of its intended method of operation. I refer here to the initial concept of the program which charged the Office of Saline Water Conversion with undertaking to interest private industry in working toward a solution to the problem. To state the situation rather baldly, this was very appealing and in apparent contrast to procedures employed by the Government in other fields considered by some members of industry to be wasteful and extravagant. Mr. Jenkins' able presentation of his proposed program and his obvious realization of the practical problems involved was effective in inducing the Whiting Corp. to divert some of its efforts to this program even during a period of business activity which

strained Whiting's resources. The pilot plant was to be erected on Harbor Island, N. C., where through Mr. Jenkins activities the International Nickel Co. had been induced to donate, without cost to the Government, the space necessary for the test installation. This same company also made available steam, utilities, and other facilities on a very reasonable basis, thus holding the cost to a very low figure. Whiting Corp. agreed to donate, without cost to the Government, the necessary long-tube vertical evaporator in which the tests would be performed. Needless to say, this evaporator was especially designed to yield the maximum degree of test information. This company also agreed to furnish on a nonprofit basis two additional evaporator bodies of the forced-circulation type required for use in conjunction with the long-tube vertical evaporator. In looking back on this program it seems quite clear that Mr. Jenkins carried out his instructions in a highly effective manner, because private industry is obviously very much involved in this project and the utilization of Government funds was kept to a minimum.

As the contract evolved, it was decided that the plant layout, erection, and test work should be accomplished principally by Dr. Badger and his associates operating under a subcontract from Whiting Corp., who was to be the prime contractor not only to insure continuity of the work in the event of unforeseen occurrences, but also to furnish without cost to the Government ordinary business facilities.

It would perhaps be of interest to this committee to understand in somewhat more detail both the structure of the intended full-scale plant and the relation the plant at Harbor Island bears to the final design. The large-scale plant is to be a multiple-effect evaporator which consists of a number of evaporator bodies arranged to operate in series. These are long-tube vertical evaporators made up essentially of a bundle of tubes arranged in vertical position and surrounded by a shell into which steam is introduced to heat the tubes. The liquid to be evaporated, in this case water, enters the bottom of these tubes and travels upwardly at high speed discharging into a vapor head on top of the evaporator where the unevaporated liquid is separated from the vapor. The vapor so generated is used as a source of steam to heat the next effect or body upstream while the unevaporated portion of the liquid is led to the next effect downstream. If only a single evaporator body or a single-effect evaporator was to be employed, 1 pound of steam, which is the steam resulting from the evaporation of 1 pound of water, would evaporate slightly less than 1 pound of water. This same 1 pound of steam, however, can be made to evaporate about 9 pounds of water if 10 effects or bodies are used in the manner described. Quite obviously, this is a very high order of heat economy and is effective in reducing the total cost of the process. The vapor generated by the evaporation of water in each of these bodies is at a somewhat lower temperature than the steam used in that body to cause evaporation. Thus, when it is employed to boil the water in the next body, the boiling must occur at a lower temperature which in turn means at a lower pressure. Thus, each body in the series must operate within prescribed limits of temperature, pressure, and solids concentration.

These variables are known to effect the formation of scale, and it was to discover the precise effect as well as its cure that the test installation at Harbor Island was devised. In this test installation 1 of the 3 evaporators employed is utilized to evaporate sea water to the desired degree of concentration. This partially concentrated water, at the desired temperature, is then introduced into the long tube vertical evaporator in which the desired degree of vacuum is maintained and is pumped through this evaporator at a known rate thus duplicating very largely the conditions which would exist in any given evaporator body forming a part of the series of the evaporators employed in a full-scale plant.

In the operation of the proposed large-scale plant, it is not contemplated that all of the ocean water entering the plant will be evaporated to dryness. In the first place, this would yield in a short period of time a respectable mountain of solids which would accumulate with such speed as to make its disposition a serious problem. Therefore, only part of the sea water is to be evaporated. Of equal importance is the effect of the amount of water to be evaporated on the formation of scale. Sea water is made up of a number of different salts such as calcium carbonate, calcium sulfate, sodium chloride, and the like. As ocean water is evaporated, these elements precipitate generally in sequence, each according to its solubility. The first to precipitate is calcium carbonate or lime which is followed later by calcium sulfate or gypsum which may or may not

precipitate depending on how far the evaporation is carried. Precipitation of calcium carbonate as a scale is due in part to a reduction in the acidity of the water which is caused by evolution of carbon dioxide during the heating process. It has been found that the precipitation of this form of scale can be largely inhibited by maintaining the acidity of water at the proper level. This is currently being investigated at Harbor Island and the work has progressed to a point where we are not quite sure that scale can be prevented by the addition of proper amounts of acidic material. This work is continuing to determine the minimum quantity of acidic material which must be added and also to obtain at least an initial indication of the rate of corrosion which can be expected. It should be noted that this finding confirms investigations conducted by the Corps of Engineers several years ago in connection with operation of potable water distillation units in remote areas.

Another method of preventing the formation of scale currently being investigated at Harbor Island is known as the sludge recirculation process. This system is based upon a peculiarity in the behavior of solutions which precipitate crystals. As the solution reaches saturation for the particular solid and the material is ready to come out of the solution in solid form, it will by preference deposit on an already existing crystal of similar material in the immediate area rather than deposit on some surface such as the wall of an evaporator tube thus allowing the crystal to grow larger and permitting the evaporator tube to remain free of scale. Here again this process closely resembles a similar process currently employed by salt manufacturers who successfully overcome the scaling problem in their evaporators by circulating a calcium sulfate slurry through the evaporators with their concentrated salt solution. Although the comparison of the two systems is not exact, it seems quite reasonable to believe that a similar result is attainable with sea water. The third evaporator, a forced circulation machine, at the Harbor Island test installation was installed to permit the formation of the slurry required for circulation through the long tube vertical evaporator. In this method of operation test work on this system has not yet progressed to a point where a report can be made but it is considered a very promising avenue of investigation and is scheduled for intensive study in the near future.

There are strong indications that the test work at Harbor Island will in this calendar year demonstrate the feasibility of a scale prevention system applicable to the process here under consideration. Thus, it has a direct bearing on the proposal currently before Congress for the construction of a large-scale plant intended to produce fresh water from ocean water. Quite possibly this proposed large-scale plant would uti'ize multiple effect distillation and could quite possibly have a production rate of 17 million or more gallons per day of fresh water. The data available is not sufficient at this time in our opinion to justify embarking on such a project. If undertaken at this time, the plant would in all probability require considerable modification before it became a unit capable of producing water at the desired low cost. Changes can be made in a plant of this size only with considerable difficulty and at substantial cost. The chances of modification being required are unfortunately substantial. Considerable advantage could be obtained, however, through the construction of a somewhat smaller plant of pilot line size having a production capacity of perhaps 1 million gallons of fresh water per day. An installation of this size would not be capable of realizing fully the low costs predicted for a large plant but would be sufficient in size to supply the data necessary for the proper design of a large plant. Furthermore, this data would be in all probability quite reliable in predicting with considerable accuracy the precise cost of water from a large-scale plant. This proposed pilot plant would not necessarily be utilized solely for experimental purposes since it is highly probable that there are many areas requiring a system having a capacity of approximately 1 million gallons of fresh water a day. This system would constitute a vital asset to such a community and the relatively high cost of the water produced by the plant compared with a large-scale plant would still mean a savings in water cost to residents of the area.

It is understood that the Congress attaches considerable urgency to this program and has perhaps developed the feeling that matters have been proceeding at too sedate a pace. Some time could be saved by promptly authorizing the construction of a 1 million gallon per day plant because the time required to carry out the initial engineering for such a plant would be sufficient to permit

completion of the test work currently in process at Harbor Island. Thus, the results of the Harbor Island work could be applied to the pilot plant without the loss of time and 6 to 9 months would be saved. It should be noted that many of the problems which would be encountered in the construction of a large-scale plant at this time would not be involved in the construction of the proposed pilot plant because evaporator systems of similar or greater capacity are already in existence and proven answers to many of the problems are therefore available. For example, Swenson Evaporator Co. is currently fabricating a seven-effect evaporator for the Union Bag-Camp Paper Corp. at Savannah, Ga., which will have an evaporation rate of 586,000 pounds of water per hour. This is equivalent to a production of approximately 1,700,000 gallons of water per day.

Quite possibly the adoption of this proposed course of action might delay the construction of a large-scale plant by a year or two. However, it would increase so greatly the chances of success in the large-scale plant that the procedure is highly recommended. It is considered to be of the utmost importance, both to the Government and to the country as a whole, that the first large-scale plant be successful in producing water at a low cost, because if it does not, the entire project may suffer a setback from which ultimate recovery might be delayed many years. The costs of the water must be calculated by industrial standards and must recognize all elements of cost if industry is to be induced to invest its capital in the construction of additional plants.

I cannot close this testimony without further reference to the Office of Saline Water Conversion and to Mr. Jenkins in particular. It is my personal opinion that the Congress should offer their commendation to Mr. Jenkins and to the Department of the Interior for carrying out their instructions so ably. In all of his contacts with us he has shown a high order of integrity and has always placed the interest of the Government first, but in such fashion as to make participation by private industry acceptable and interesting even if at their expense. Furthermore, although we do not possess a detailed knowledge of other negotiations, the list of cooperating companies is impressive and if their cooperation has been obtained along lines similar to those involving Whiting Corp., it would indeed represent an unusual and beneficial accomplishment. Mr. Jenkins' efforts have made available to the Government the resources of knowledge of private industry where much of the knowledge necessary for a successful solution to this problem resides. The program has been further characterized by an absence of delays unfortunately common in other transactions involving the Government. Maximum utilization has apparently been made of the best opinion available which is considered highly important, because we know all too well that many of the initial decisions must be based primarily on opinion if the excessive waste of funds is to be avoided. From a personal standpoint, I am particularly impressed with his performance as your representative since he induced us to enter into this program at a time when we were actually turning away cash customers due to our already heavy backlog of orders. When you further consider that this decision was also reached with the knowledge that to a large degree the work would be performed at our own expense and that it would in turn prevent our taking some of the readily available business at a profit, I am sure you will agree that the situation is not conventional. May I hasten to add, to avoid leaving you with the wrong impression, we expect to obtain some valuable information from the work so in at least some sense we are receiving a form of compensation. It is our intention to continue active participation in this program to the maximum degree possible until a successful conclusion is reached.

Mr. MOREY. I have been particularly interested in the comments of the preceding witnesses, Mr. Chairman, particularly from the standpoint of dollars—costs. In other words, there is no mystery whatsoever in how to make fresh water out of salt water. Anybody who has a tea kettle and a cake of ice can make fresh water out of salt water, but at a price. It seems to me this entire program from its very inception must hinge around cost. The cost is the all-important thing. It also seems to be an area on which everyone is entitled to their own opinion, and it becomes difficult because the matter of judgment necessarily enters into costs when you speak of a large-scale development.

It seems unnecessary to point out in any great detail that the availability of fresh water to human beings is about as fundamental a need as could be envisioned in any area, and is perhaps second only to air itself.

I have been interested in our several years' contact with this program and the possible effects that this program might have on our foreign relations. It was my privilege to attend the Solar Energy Conference in Tucson, held a couple of years back, where representatives from all over the world were discussing the application of solar energy. Needless to say, the availability of fresh water entered into that, because the areas that are the shortest of water, speaking of the world as a whole, appear to be those that have the maximum solar energy. Perhaps they have an excess. Generally, the southern Mediterranean countries, Australia, and similar areas are very short of potable water supply.

In this particular instance, referring perhaps for the moment to distillation, many of those areas are fairly rich in available fuel. I very much doubt that it would make our foreign friends angry with us if we should make available to them a reasonably economical process for augmenting their fresh water supply. So the problem then should be considered perhaps on a larger basis than the needs of the continental United States alone. It has a possible influence, and an influence, I might add, that goes to the individual and not to the Government as a whole.

Mr. JONES. Do you recall that the amendment, Public Law 111, of the 84th Congress, took that fact into account and provided specifically that cooperative agreements could be entered into with foreign countries for that purpose?

Mr. MOREY. I do recall that. This is not a matter of suggesting something that is new; but since this was somewhat of a general review of the problem as a whole, I felt it was well worth mentioning because the areas that are currently trouble spots are also not oversupplied with fresh water.

Our activity in this field has been carried on principally through a wholly owned subsidiary of the Whiting Corp. called the Swenson Evaporator Co. This company has been in the evaporator business for somewhat over 60 years and has continuously dealt in the manufacture of evaporating equipment of various types. One of the areas in which I felt the committee might be the most interested is the application of evaporation to paper mills, because it is in that area that the quantities involved approach those being considered by the committee.

In the paper industry it is necessary to extract from the wood the lignin and other waste material in the form of black liquor; and to avoid stream pollution, this material is then evaporated, the salts are recovered, and the process is virtually self-sustaining because the lignin itself is later burned and used to supply steam to carry on the evaporation itself.

Now, these in some instances reach rather respectable size. There has been an operation in the southern part of this country, a seven-effect, long-tube vertical evaporator that has an evaporation rate in excess of a half million pounds per hour. I think this is significant because, on the basis of many years of operation, it is possible to

determine rather closely the actual operating costs on an all-inclusive basis, including your capital investment, management, and other allied matters.

I might mention in that connection that we are currently building what we believe to be the largest LTV, long-tube vertical evaporator, which is a specific form of evaporator, of the Union Bag-Camp Paper Corp. in Savannah, Ga. This has an evaporation rate of approximately 586,000 pounds of water per hour, which would be the equivalent to a production of something approaching 1,700,000 gallons of distilled water a day. This approaches, or perhaps in some cases exceeds, the size of the pilot plant which I believe is under discussion here today.

I think it worth mentioning that these are known industrial processes. They are not subject to speculation. They do not represent perhaps the results of recent research, but they are nevertheless capable of very accurate cost calculations; and there is very little doubt as to whether or not the process will work.

It might be of interest to this committee to review somewhat briefly the general history that has been followed in our work in this field. We have worked for many years quite closely with Dr. W. L. Badger at the University of Michigan. He has done a great deal of research work for the company and is currently a consultant to us and also to the Office of Saline Water Conversion. We have cooperated quite closely in this work. In the very early proceedings, a cost of evaporation was stated to the Office of Saline Water Conversion, which we suspected was excessive. And in checking through, based on current industrial costs, we found it was quite high compared with what could be done.

Now, this initial plant on which the costs were calculated envisioned the use of 10 effects operating in a series. When I speak of an "effect," you might visualize it as a long, upright, cylindrical boiler. As the water is evaporated in this particular body, the vapor which is evolved is used to heat the next effect. So, instead of getting approximately 1 pound of water for 1 pound of steam, we can get something in excess of 9 pounds of water for 1 pound of steam by using 10 effects instead of one. This is not a recent or startling discovery, but sometimes it is not appreciated when you speak of the multiple-effect evaporation. That is the keynote of its success.

Some preliminary cost estimates were prepared jointly by Dr. Badger and Swenson Evaporator for the Office of Saline Water Conversion, which indicated we might be able in a properly designed plant to attain one of their targets which was approximately $100 per acre-foot cost for potable water. We don't feel today that we can reach their target price for irrigation water. The volume is simply too large. This had some appeal to the Office because it was based on engineering of so many years standing that it was capable of verification beyond reasonable doubt. A more careful review tended to confirm this and to emphasize, as I believe Mr. Blohm mentioned, the adaptability of this process to power generation. And in fact the most economical figures evolved were those in which the discharge of a turbine, slightly modified from conventional practice, was utilized to produce the fresh water.

Mr. JONES. Where was that, do you recall?

Mr. MOREY. Where?

Mr. JONES. Yes.

Mr. MOREY. These figures were intended for general applicability throughout the United States, but they would necessarily require that the plants had easy access to salt water.

Mr. JONES. Oh, I thought you had reference to a particular plant.

Mr. MOREY. No; this cost calculation utilized the figures dictated by the Office of Saline Water Conversion. It would be applicable, I would say, to the coastal area. It should be noted, perhaps, that distillation process is not sensitive to the salinity of the water being treated. It is completely applicable to the treatment of ocean water with its high percentage of solids. It will also operate without any question on the mildly brackish water found in the underground reservoirs on the eastern slope of the Rocky Mountains. However, it is not necessarily the most economical for that particular application. I feel it quite possible that other processes may be more applicable to the mildly brackish water. On the ocean water, to the best of my knowledge, this offers the best potential as far as low-cost large-scale production is concerned.

Now, this was all very nice, but unfortunately it had an important hooker in it. Dr. Badger pointed out, and we subsequently confirmed, that this cost analysis is applicable only if you are able to prevent the formation of scale in the boiler tubes. If that does not occur, the heat transfer coefficient will be reduced and the process will not reach its cost objective.

We were not wholly without help here. We were familiar with work done on the island of Curiso, where water is supplied at least in part by evaporation with their scale-prevention techniques. We had the history of many large chemical processing plants to go on, and we felt there were two basic attacks could be made on this problem. One has to do with the addition of acid; in other words, control of the acidity of the water. And the other has to do with a recirculation of a solid material having the same composition as the scale through the evaporator. This has been very effective in several of the large salt plants. Crude salt, as it goes thorugh its purification process, contains gypsum, calcium sulfate, which is one of the worst forms of scale. By circulating a sludge with salt through the evaporator, we were able to cause the scale-forming solids to form on the crystals already present in preference to formation on the walls of the tube. That process is not hypothetical. It is in operation today and is highly effective.

The translation of that to salt-water treatment is not exact, but it gives good reason to believe that it will be successful. Because both of these have an industrial background, we concurred in Dr. Badger's recommendation that these two processes be tried. And as a result this plant at Harbor Island, N. C., was designed and built in part with funds provided by the Office of Saline Water Conversion.

I think in that connection I would like to hand a bouquet to Mr. David Jenkins, of the Office of Saline Water. He was able to get the International Nickel Co. to provide without charge to the Government the site and to supply steam and other utilities at a very nominal cost. He induced us to supply the long-tube vertical evaporators without charge to Government and to supply the two additional evaporators required on a no-profit basis. He has obtained the services of some

experts in this field that I feel are entitled to serious recognition. As a result, that pilot plant probably represents a minimum cost to the Government.

The work is not complete as yet. It has gone far enough so that I think we can safely say we know we can prevent formation of scale by the addition of very modest amounts of acidic material. That much of the work has been completed. We have yet to determine with a high order of accuracy the precise corrosive effects of this acid material on the evaporator; but the initial indications are that it will not be serious. We have only very sketchy data on the second of these processes which is the sludge recirculation, but those initial tests also are highly favorable.

In the event we are able to prove conclusively through this pilot plant work that the formation of scale can be prevented, then I believe it would be quite possible to attain these target costs or come very close to them insofar as water for human consumption is concerned.

That, incidentally, is a point on which I believe any one of several companies in the United States would be competent to comment, whether they were manufacturers or firms of consulting engineers with no particular interest in equipment application. You should be able to obtain reliable opinion not influenced by a possibility of making a sale—which, by the way, is of interest today.

It is my impression that the committee is highly interested in moving this program along as rapidly as possible. At the same time, I think it important that you do not proceed at such a high rate of speed that you take a chance on the construction of a large-scale plant which will fail to even reasonably attain its cost objectives. If you build a large-scale plant before you have adequate data, you may then be forced to change that plant after it is up; and changing the piping arrangement flow sheet of a large-scale plant is an expensive and time-consuming operation. Basically I believe that is why not only I but other witnesses have strongly recommended the construction of an intermediate scale pilot plant.

Mr. JONES. Mr. Morey, I don't think we will do that, because with a million dollars a year to run the whole program, I don't see where you are going to get any large-scale plant other than a few pilot plants, and they are going to have to be modest.

Mr. MOREY. All right. I would hate to attempt to dictate the economy of the Office.

Mr. JONES. I'm not speaking for the Office, but I am just making a good guess.

Mr. MOREY. If we are able to obtain funds sufficient to erect a pilot plant large enough to give reliable data, I believe from that you could step to a large-scale plant with a considerable order of safety. As to saving time on the construction of the pilot plant, it would not be out of reason to initiate the engineering required for that at this time, because by the time it was necessary, the results from Harbor Island would be available and could be applied without time loss. This might save 6 to 9 months.

I do not believe that this pilot plant would necessarily be solely experimental, for there are undoubtedly many communities throughout the United States that would be very happy to not only have a million gallons additional fresh water a day but quite possibly would

get that at a cost less than they are now paying. However, I'd like to make clear that this pilot plant will not produce fresh water at the target price. It will be more expensive necessarily because of its reduced scale. Its intention primarily from a research standpoint is to answer engineering questions and provide design data for the larger plants.

Incidentally, I do not consider it beyond reason that private utility interests could be interested in construction of a somewhat larger plant at this time.

Mr. JONES. Can they get fast tax amortization, do you know?

Mr. MOREY. Could they get tax amortization? I'm afraid——

Mr. JONES. I don't know. I just asked that question. They must not have because they'd have been down there if they could have gotten it.

Mr. MOREY. Mr. Chairman, even if they cannot get tax amortization on an accelerated basis, I believe the economics of the situation might still justify proceeding with the plant.

You have asked many of the witnesses whether or not they had any comments regarding the cooperation they have received from the Office of Saline Water Conversion. I can only tell you that ours has been excellent, that we not only have no criticism but I am at least personally very much impressed with the manner in which it has been handled.

I like the idea of having a Government agency come to private industry and attempt to interest private industry in spending some of their own funds on the solution of these problems. To my mind, that is excellent planning. We are happy to cooperate in such a program. I believe it has been carried out in this instance. It is rather well proven by the impressive list of companies that have submitted proposals and performed actual work. I rather feel that other representatives of industry will agree with that.

Mr. JONES. Thank you very much, Mr. Morey.

Do you have any questions, Mr. Chairman?

Mr. DAWSON. No.

Mr. JONES. Mr. Fascell?

Mr. FASCELL. No.

Mr. JONES. Thank you again, sir.

Mr. W. L. Badger, chemical engineer, Ann Arbor, Mich.

## STATEMENT OF W. L. BADGER, CHEMICAL ENGINEER, ANN ARBOR, MICH.

Dr. BADGER. I want to make a slight introduction of myself because there is one factor that makes for confusion, and that is that the name Badger has been connected with two entirely different processes. There is no connection between the two whatsoever. The connection is entirely accidental. There was an E. B. Badger Co. in Boston, which has been succeeded by the Badger Manufacturing Co.; and that was a totally different branch of the family. I not only have not been connected with them but don't even know them.

Mr. JONES. Are you with the University of Michigan at the present time?

Dr. BADGER. No. Let me just explain very briefly what my connection with evaporation has been. For 25 years I was professor of chemical engineering at the University of Michigan. Beginning in 1917, I initiated a cooperative project between the Swenson Evaporator Co., who were then independent, and the university, by which they built their laboratory at the University of Michigan for all their development work. I was in charge of that laboratory for them and for the university for over 20 years. I have been consultant to the Swenson Evaporator Co., their successor, since 1917, which gives me about 40 years in this field.

You have my letter of April 10, 1958, summarizing my statement, which I will not read. Many parts of it have been already covered by other witnesses.

(The prepared summary of Dr. Badger's statement referred to is as follows:)

W. L. BADGER & ASSOCIATES, INC.,
*Ann Arbor, Mich., April 10, 1958.*

Hon. ROBERT E. JONES,
*House of Representatives, Washington, D. C.*

DEAR SIR: This letter is a brief summary of the main points of the testimony I am prepared to offer at the hearings of your subcommittee on the progress of saline water. I will confine my comments to the system of sea-water distillation we are proposing.

1. The process we are proposing seems to be the most promising avenue of approach at the present time. It does not require the development of new types of equipment, but depends for its success on the use of a type of evaporator well known and widely used for many years, and on the use of extensions and elaboration of principles of design also already known.

The type of evaporator we propose to use is the long-tube vertical evaporator. It has been built in sizes up to the requirements of a plant to produce 1 million gallons of fresh water per day from sea water. It has not yet been built commercially in as complex an arrangement as we propose, but this complexity offers little or no difficulty.

This type of evaporator has not yet been used on solutions that deposit scale, as does sea water. We proposed two systems for preventing scale in such evaporators: (*a*) by controlled feeding of acid, and (*b*) by the recirculation of sludge. These processes required some pilot-plant research to prove or disprove their practicability.

2. The Office of Saline Water has supplied funds for designing, building, and operating such a plant. The results to date have shown that method (*a*) is completely successful. Work on process (*b*) is underway and preliminary results are encouraging.

We have not yet developed the exact limits of acidity necessary for the success of method (*a*), but the indications are that excessive acidity will not be required.

3. To decrease the cost of the equipment, we have planned to build the evaporators of low-carbon steel. If the acid process for scale prevention is to be used, the acidity in the high-temperature parts of the system may require the use of alloys. The real answer to this question can only be solved by 6 months to a year of continuous operating in a much larger unit.

4. We suggest that a plant to produce about 1 million gallons of fresh water per day be considered. This plant is to be looked on not simply as a demonstration plant but also as a plant for further studies, especially to determine the possibilities of corrosion if the acid treatment becomes necessary. Building a plant to produce 10 or 15 million gallons a day would greatly increase the cost of repairs or alterations if they should become necessary.

The step from the pilot plant at Harbor Island to a 1 million-gallons-per-day plant is a large one, but not outside the reasonable risks of any engineering project of this magnitude. It would, however, represent much sounder engineering not to go at once to a 10- or 15-million-gallons-per-day plant at this time. After we have had 6 months to a year of experience in the million-gallon plant, the step to 15 or 20 million gallons per day would not be excessive.

A plant to produce a million gallons per day could be shop fabricated and assembled. A plant for larger capacities might have to be field assembled.

5. The sole disadvantage of the plant to produce a million per day is that it could not demonstrate the low costs we have predicted for the 17-million-gallon plant. This is because both first costs increase, and efficiencies decrease, per unit of capacity, in the smaller sizes. The million-gallon plant, however, would develop accurate data for predicting the costs that could be reached in a larger plant.

6. The recommendation that a million-gallon plant be built now, for further research and testing, does not mean that a larger plant must wait on the results of such an experimental program. The work necessary to design a plant to produce 15 or 20 million gallons a day is so great that many features (that do not depend on the results of the million-gallon plant) can be started at once. As fast as results come out of the million-gallon plant, they can be incorporated at once in the calculations for the larger plant; thus much time can be saved in the design of the larger plant.

7. Our reports to the Department of the Interior have covered two cycles: (*a*) A plant using a combination of multiple effect and thermocompression bodies, to produce only water, and (*b*) a plant consisting of a powerplant exhausting at modest back pressures to operate a multiple-effect evaporator. Such a plant would sell both power and water.

Plant (*b*) has many advantages in practice and is probably (according to our present views) the more important development. However, for the million-gallon plant we are recommending, we recommend plant (*a*). This is because the million-gallon plant is still an experimental plant. If power is to be sold, the purchaser cannot tolerate the fluctuations in output that would be caused by many contingencies that might arise in experimental operation. Plant (*b*) is the simplest to build and to operate, so that when plant (*a*) has demonstrated its ability to perform, the engineering of plant (*b*) follows directly.

If, however, cooperation with a power company could be arranged whereby adjustments could be made to correct the power-generating cycle if the water-generating cycle operated irregularly, then by all means plant (*b*) should be used.

8. Up to the present time the support we have had from the Office of Saline Water has been adequate and satisfactory. We cannot see any step, up to the present time, where more funds would have accelerated progress. Development work of the sort we have been doing is solely a matter of time, once adequate funds are available. The sympathetic and intelligent attitude of the Office of Saline Water has been a great encouragement throughout the program.

9. It may be that the problem has now reached a stage where larger funds should be available than can be supplied by the Office of Saline Water on its present limited budget. Whether these funds are to come from Congress, or partly from Congress and partly from some State cooperation, or whether private funds should be sought, we are not prepared to recommend.

Very truly yours,

W. L. BADGER.

Dr. BADGER. I merely want to state by way of emphasis what we consider that out contributions to this field have been. First, I got the idea that we could use the long tube vertical evaporator for water distillation, which has always been assumed to be a totally unsuitable type for that purpose. Its advantage is that it is the cheapest type that can possibly be built. Second, I conceived the idea that this evaporator could be built of ordinary mild steel. That is also contrary to general opinion but, on the other hand, it is based on 3 years' experience I had off and on with a little salt plant in Puerto Rico where they were making salt by direct evaporation of sea water. There we had some evaporators made largely of mild steel, and in 3 years' experience, we could not determine any corrosion.

Now, in order to use the long tube vertical evaporator for sea-water evaporation, we had to assure ourselves it could be kept free from scale. Mr. Morey has indicated that we have one string to our bow in that we had developed—now, when I say "we," I mean I and the boys who had worked under me who later went out into the salt industry and

worked out this method for preventing formation of scale in salt evaporation.

When I first became connected with the salt industry, about 1914, we expected to boil out or drill out a salt evaporator every week. We shut down Saturday morning and over Saturday and Sunday we drilled the tubes out for calcium sulfate sludge. At the present time, I know of evaporators that have been in operation without cleaning for over 7 years, in which the tubes are just as clean as the day they were put in. So we know that is successful. We could not translate that process directly into sea-water evaporation because of differences in the composition of the scale in salt evaporators and the composition of scale in sea-water evaporators, but that's what we are aiming for at Harbor Island.

Second, we knew that, irrespective of whether that method worked or not, we could prevent scale by controlled acidity; and the work at Harbor Island also had that as an objective. I can summarize that right now by saying we can prevent scale absolutely in all the bodies with a very modest acidity. Preliminary indications from Harbor Island, which have not been completed yet, are that that can be reached by an acidity that does not endanger common mild steel. I am not making that statement as flat as the one where I said we can prevent scale. We must do a little more work on it. But we believe the common steel will stand the degree of acidity that we are going to have to use.

As Mr. Morey said, preliminary indications on the sludge recirculation method have been successful, but the ones we've gotten to date are too short to be really conclusive. That work is going on just as fast as we can push it, and Harbor Island is working 24 hours a day 7 days a week. I have a crew down there keeping that in continuous operation.

In my reports to the Office of Saline Water Conversion, which were made some 2 years ago, I made some statements about costs and those have been questioned. Incidentally, may I put in two sentences off the record.

(Discussion off the record.)

Dr. BADGER. Now, there is one very unsatisfactory thing about this matter of costs which is not the fault of the Office of Saline Water. I don't know whose fault it is. I believe on the basis of honestly and carefully prepared cost estimates that I could make distilled water in a multiple-effect evaporator at the cost of $100 per acre-foot, which amounts to 30 cents per thousand gallons. Those have been repeatedly questioned. I have tried over and over again—Dr. Schroeder, incidentally, was one who questioned those figures. I have tried over and over again to get somebody to say what is wrong with my figures. I get no answer—"Well, we think the figures are too optimistic." It reminds me of the preacher whose congregation was dissatisfied and asked him to resign. He argued with the committee and the committee finally said, "Well, pastor, you certainly argufies and you certainly disputifies, but you doesn't say wherein." I can't get anybody to say "wherein" on these costs. And I still maintain that, other people to the contrary notwithstanding, we have every reason in the world to expect 30 cents—well, 30-cent water was the figure arrived at 2 years ago. Maybe we should increase it somewhat. Make it 40 cents. But

I think this talk about $100 per acre-foot, which is—I beg your pardon, I'm getting my units all mixed up. I still believe this figure of $1 per thousand gallons which has been quoted repeatedly yesterday and today is quite out of the question. We can make it for a lot less than that.

Now, I want to assure you that in making our figures we have got actual bids on the evaporator from the Swenson Evaporator Co. and on the other equipment involved from equally responsible companies in the field; not guesses, bids. And the costs of erection and so on were taken from not only our own experience but the Swenson Evaporator Co.'s experience. That figure certainly has been questioned and I certainly want to defend myself against those questions until I can get something more accurate.

Another thing that Dr. Schroeder said the other day was regarding the cost of a pilot plant. He stated, and I made notes of this, so I think I can quote him accurately, that a plant to produce 100,000 gallons a day would cost a million and a quarter dollars and that a plant to produce a million gallons a day would cost $12 million. I believe that a plant to produce a million gallons a day can be built for only a little over a million dollars today. And I can emphasize that from an item that was cited by Mr. Morey in his testimony, that the Swenson Evaporator Co. is now constructing an evaporator that is going to have a capacity of a million and three-quarters gallons a day. I happen to know what the price involved in that is, and it is exactly the same order of magnitude as the figures I used in my own estimates.

Now, we believe, on the basis of Harbor Island, that plans should be made at once, right now, to start the engineering of a plant to produce about a million gallons a day. And the reason why I want to go to that is this: If the sludge recirculation methods works, there isn't very much of anything in the way of problems to be solved by a plant of that size. We've got no final results on sludge recirculation, but we will probably have them before the engineering on a million-gallon-a-day plant can be completed.

If we should have to go—now, this is a big "if;" and the longer the work at Harbor Island goes on the less significant that "if" becomes—if we should have to use acid control to prevent scale, then only by several months' operation of a big plant can we really tell what corrosion is going to mean. It's not possible to take small tests-tube laboratory experiments on corrosion and predict what will happen in a big plant. Corrosion is too difficult to tie down. But with the 6 months' experience in a million-gallon-a-day plant, we would know exactly what the acid control would do.

Mr. JONES. What makes it so treacherous, Doctor?

Dr. BADGER. We don't understand corrosion. We don't understand it. And you can have the widest fluctuations between laboratory experiments and results in practice. At one time when I was doing a lot of research with the Dow Chemical Co., we were concerned with the attack of certain solvents which were acid, on the metals of construction for a dry cleaning machine; and we made several thousand laboratory runs where we put test strips of various metals in a vat and heated them for long periods of time. When we came to build the big machines, the results were totally different. We can't predict. It just simply—there are too many factors at work that cause corrosion

to be able to predict. I'll put it this way: If the small-scale tests indicate that a metal is perfectly stable, that will probably be the case in practice. If the laboratory results report that a material is going to dissolve in short order, then you know your answer is correct. But in between the two, we can't answer that.

Now, I believe that, even if we have to go to the acid control method, we will use acidity so low that we won't endanger carbon steel. But it really takes 6 months' run to prove that in a big machine.

Now, the reason why we have settled on a million gallons a day is that we feel the cost data which we could get out of that would enable us to predict costs in any size plant. Much less than that, it would leave more uncertainties in the cost calculation. Further, a million-gallon-a-day plant is big enough so that many communities would find that million gallons a day of water extremely useful today.

If I only had the results on corrosion, I would be willing to build a plant, start on the engineering of a plant, today, to make any quantity of water you want to up to 15 million to 20 million gallons. All the other factors we've got completely under control. If I could use sludge recirculation, which we are working on just as fast as we can at Harbor Island, I wouldn't even have that problem. But to blow up your plants too many times, it's just asking for difficulties. And we feel the step between Harbor Island and a million gallons is not an excessive step. We feel the step between Harbor Island and 15 million or 20 million gallons-a-day plant is pretty big.

Mr. JONES. What do you think that plant design would cost?

Mr. BADGER. If the plant is going to cost a million dollars, the engineering would be somewhere between $80,000 and $100,000. I think a million gallons-a-day plant at today's prices, which are higher than those which I used in my own reports 2 years ago, would be not a million dollars but maybe a million and a quarter. And therefore I would expect it would be somewhere between $80,000 and $100,000 for the engineering.

Now, I believe that's all I have need to add to the other witnesses' statements.

Mr. JONES. Mr. Badger, what would be the cost of the scale control in these plants? Would it be——

Dr. BADGER. Zero. In the order of a cent per thousand gallons if we have to use acid. Nothing if we can use sludge recirculation. Maybe $15,000 or $20,000 more for equipment in the first cost of the plant, which you can't find in a million-gallon plant.

Mr. JONES. If the cost was that low, why don't you just go ahead and use your acid now and go ahead with your plans on that basis?

Dr. BADGER. There is this ghost of corrosion hanging around in the background which I'd like to dodge. Now, I would be willing, if I could have a million-gallon-a-day pilot plant to study corrosion, to start right now. I really believe that before the engineering could be finished, we'd have results from Harbor Island and it would make the acid unnecessary.

Mr. JONES. Does any other university or other research agency do work on problems similar to the one that you have?

Dr. BADGER. I heard testimony from the Navy men yesterday that they have gone to control acid feed in order to prevent scale and that

they have prevented scale that way. My problem is to see whether I can do that without involving the use of expensive alloy construction.

Mr. JONES. Any questions, Mr. Chairman?

Mr. DAWSON. No; but I certainly appreciate the testimony I have listened to.

Mr. JONES. Mr. Indritz?

Mr. INDRITZ. What is the rate of progress on the testing in your still?

Dr. BADGER. You mean the plant down in Harbor Island?

Mr. INDRITZ. Yes.

Dr. BADGER. The boys are turning out results just as fast as they can. That is working 24 hours a day 7 days a week. We have finished the acid runs, most of them. We are starting on the scale runs. The last report I had from down there was that the two preliminary runs, which were not too conclusive, were completely successful. But I am not banking on that yet. Those runs are too short.

Mr. INDRITZ. When you appeared before the Committee on Interior and Insular Affairs about a year ago, March 1957, and you were asked how long these tests might take, you indicated approximately between 6 months to a year. About how much longer would the tests still take before you could get definitive results?

Dr. BADGER. We didn't get this plant wound up until the first of this year, so we have been going 4 months. If the Lord is with us and everything comes out well, 6 months more would lick the thing.

Mr. INDRITZ. Did your 30 cents figure also include costs for storage, distribution, pumping?

Dr. BADGER. Did not.

Mr. INDRITZ. Is it only the cost of producing the water itself?

Dr. BADGER. Producing the water, because in almost all of the problems that have come up to us in the meantime, the water has been needed by communities where they already have the distribution system, where our new plant would merely be required to discharge into existing distribution systems.

Mr. INDRITZ. Might that account for the discrepancy between your cost figures and Dr. Schroeder's?

Dr. BADGER. Schroeder was putting in some storage facilities, I think, which, if you have an existing municipal distributing system, you don't need.

Mr. INDRITZ. Are you familiar with the Westinghouse two-unit multiple-stage flash evaporation plant?

Dr. BADGER. Just what I read in the papers.

Mr. INDRITZ. We received a letter from Westinghouse March 28, 1958, concerning plants which produce about 2½ million gallons of water a day. They state they have "successfully minimized two of the most troublesome problems normally associated with sea water distillation—scaling and corrosion." Do you know what they have done?

Dr. BADGER. I do not. That's company information.

Mr. INDRITZ. And you don't know, therefore, whether their methods are any better than yours.

Dr. BADGER. I'm guessing they are using acid control, because that's the direction in which practically everybody in this field is drifting.

Mr. INDRITZ. We are also informed that the proposed plant being built by Singmaster & Breyer at Aruba is scaleproof. Do you know anything of that plant?

Dr. BADGER. No, I do not.

Mr. INDRITZ. Do you know whether the Office of Saline Water is trying to secure such information?

Dr. BADGER. I do not know.

Mr. INDRITZ. I have no further questions.

Mr. JONES. Thank you very much, Doctor. It has been a pleasure to have you here, sir.

Our next witness is Kenneth Hickman, chemical engineer, Rochester, N. Y.

Good morning to you, Dr. Hickman. We are glad to have you today, sir.

(Dr. Kenneth Hickman's prepared statement is as follows:)

STATEMENT OF DR. KENNETH HICKMAN, CHEMICAL ENGINEER, ROCHESTER, N. Y.

Mr. Chairman, these notes have been compiled without knowing what will be offered in testimony, and many of my points may have been made more ably, or disposed of entirely, by others.

In wondering whether I could be useful to this committee I have been troubled, because I do not know how urgently the United States Government really wants to convert saline water.

The most extraordinary things are wanted in science today and extraordinary sums of money are forthcoming to satisfy them. There are bigger and better particle accelerators at half a billion apiece, bigger and more earth satellites—and now $2 billion is being mentioned seriously as a right and proper price to land a man on the moon. By this scale it appears we don't want converted water at all because we are still fussing around with support at the $1 million annual level.

Besides unlimited funds for certain sorts of science, there are also plans to relieve the depression by public spending. With $1.8 billion currently voted for roadbuilding I thought a useful yardstick would be to see what the same sum would do in the present state of the art to convert salt water. The current total capital cost for successful conversion machinery, with the powerplant to run it, is around $3.50 per gallon-day in large sizes, so $2 billion would supply converted water to more than half of metropolitan New York City at ordinary usage and to all New York with restricted usage. The undistributed remaining costs would be around $1 per 1,000 gallons, plus or minus 25 cents; are these capital and operating costs fantastically high? For the past, the answer must be yes. For the future, we wonder.

To find new natural water to the tune of 600 million gallons a day and bring it by aqueduct might well cost more for New York City. In the event of attack by nuclear, poison, or germ weapons, aqueduct water would remain poisoned, converted water would soon be potable. The chemical damage to an aqueduct could be catastrophic, but at least some of a series of scattered conversion plants would remain operative. Would a $2 billion road to water conversion lead anywhere? It might become a road to survival in these times of world tension. Then, should not every maritime city have sea water conversion facilities? Ultimately, yes; but the immediate need would seem to be to get one sizable plant into integrated operation in a large east coast city. By the billion dollar yardstick, then, we have advanced to a place where we are already in a position to take action—should we so desire.

A technical yardstick tells a different story. Summarizing for my argument some well-known facts, all major power sources are thermal in origin. The common fuels burn at about 2,500° F.; water distills at 212° F. Salt can theoretically be separated from sea water with expenditure of 1 B. t. u. of heat per pound of product, but it takes 1,000 to separate it by distillation. The game, played by inventors and engineers for the past 100 years, is to see how many times an initial 1,000 B. t. u. can be reused before discarding to waste. One device is the multieffect still when the heat drops stage by stage from, say

220° F. to 90° F., making a repeat quantity of water at each drop. The other scheme has been to turn all the available heat energy (one-fourth to one-third) into power and employ a mechanical or electrical conversion process. The score for sea water, has been something like this:

For multistaged stills: 3 to 6 times reuse of original heat.
For mechanical, electrical methods: 10 to 15 times reuse of original heat.

About 30 years ago, there dawned one of the great evolutionary ideas in water conversion engineering—coupling: using the major heat drop from 2,500° F. to 250° F. for the production of power and then using the steam in a multistage still. More simply, a powerplant is coupled to a water still, cutting out the low pressure turbine and condenser. The famous Aruba plant has operated in this way for 20 years. Courtesy of G. E. Sonderman who is breaking in the latest addition to the plant's capacity the score will shortly be:

For power generation: 17.5 percent efficiency (30 to 35 percent)
For water conversion: 4 to 5 times reuse (5 to 6)
For water cost: $1.00±.25 ($1.75±.25)

The figures in parentheses are what the power or water plant would do separately. i. e. uncoupled.

Now the lowered cost for coupled water comes from the sale of the (byproduct?) power. Were the power to be used in mechanical converters then, instead of getting a cash credit, we should get additional water and the score would look like this:

For water conversion: 8 to 10 reuses of heat
For cost: $1.12±.25

A little more expensive perhaps but a much greater yield of water from the original fuel and an uncoupling of the installation to the extent that there is no longer an interdependence of power and water demands.

A technical progress chart can now be compiled.

| | Reuse of 1,000 B. t. u. per pound, water | |
|---|---|---|
| | Actual | Equivalent |
| Simple distillation | 1 | |
| Multistage still, past and present | 3–6 | |
| Compression stills | | [1] 10–15 |
| Membrane-electric | | [2] 5–50 |
| Coupled plants: | | |
| Powerplant to multistage still | 2½–5 | 5–10 |
| Plus compression stills | | 6–12 |
| (Tremendous gap, to be filled by research) | | 50? |
| Ultimate millennial means | | 100 |
| Theoretical, unobtainable | | 1,000 |

[1] In terms of original fuel allowing for powerplant losses.
[2] According to salt concentration.

Taking credit for sale of power. By this yardstick, you see, we still have most of the way to go.

Although there is now ample and welcome room for more coupled plants, progress I wish to suggest does not lie chiefly in more and better coupling. If our powerplants are compared with a drawer full of smaller marbles and our water converters with a drawer full of larger marbles, then mixing the two drawers full we find that the marbles will occupy less room (analogous to lowering costs) because the smaller marbles can occupy the voids between the larger. We can shake them down a bit more but there is a limit to the contraction. Further economies can come only by altering the marbles themselves, i. e., improving the basic conversion processes.

Even favorable coupling has its drawbacks. It presupposes a fixed relation between need for electricity (or equivalent service) and need for water. Operation must be continually at full load if the economy is to be preserved. It assumes tacitly that power consumption is the controlling cost. The truth is that even if the power were free, the present cost of converted water would hug the dollar range (per 1,000 gallons) because of the high cost of conversion machinery, maintenance, and labor, to say nothing of the premises, outside services, pumping

stations and what not which, as Sonderman points out are generally forgotten in the projected cost accounting. Lastly, most of the world's water needs cannot be taken care of by coupling, because the majority of would-be users of converted water are widely scattered and require independent conversion units of all sorts of capacities.

A critically needed independent unit, it seems to me, parallels in function the coupled plant suggested for New York City. It is the portable unit, perhaps like a restaurant coffee urn or perhaps larger, and mounted in a station wagon or truck that can be moved singly or by legions to points of disaster to give drinking water instantly where there is flood, fire, or earthquake; to combat the spread of disease in epidemic areas but, above all, for civilian and military survival use in time of war. More of this theme in my concluding paragraphs. I wish to pass to the Government's function, as I have been privileged to watch it develop through the Office of Saline Water.

If there is one thing that impresses me, it is the fairness and impartiality and the unfailing courtesy with which the limited resources of the Office of Saline Water have administered. No invention or backer of a process of any merit at all has been turned away. Support has been given to every conceivable plan until it has manifestly disqualified itself. The major schemes, and I have had the good fortune to be connected with one of these, have been administered sympathetically and appraised and reappraised by the Office's personnel and by outside consultants. As approval has been gained, the projects have continued their orderly development, outlined in a succession of annual reports and technical brochures.

Perhaps the greatest distinction and usefulness achieved by the Office has been the coordinating and focusing toward Washington of work in water conversion being done throughout the world. The symposium held last November was a model of its kind for the exchange of knowledge.

I must confess, however, that in this very orderliness I seem to find something missing, some precious ingredient. Nowhere do I detect that sense of urgency which is the precursor to action. You cannot push an invention to perfection by a committee of evaluators, be they ever so expert. There must be a singleness of purpose, a blind refusal to concede failure, a fury and a passion to forwarding the drive. With Senator Anderson, I ask where is this?

My diatribe scarcely involves the Office of Saline Water or its personnel, for whom I have high regard. It is aimed at the entire framework of thinking and finance within which the Office must work. Unless and until we, collectively, can begin to think as imaginatively and purposefully about water for the world as we do about men for the moon, I don't think we will get cheap converted water or deserve to get it.

Let us assume for the moment that the Office of Saline Water's mandate and budget should both be dramatically increased, what changes would I recommend? At least it is obvious that the Office would have to be enlarged and I would recommend that an executive manager be made available in the No. 2 position to free the Director for matters of top policy with its many liaison duties. I believe there is great need for traveling field inspectors, engineering and fiscal, to operate in pairs. Their duties would not be to direct or appraise but to report the status quo and the integrity of effort applied to the projects, which latter shall have been completely delegated in management to the contractors. This would eliminate the delays and inefficiencies that can sometimes result when responsibility is vested in a group of contracting parties.

This kind of inefficiency is always aggravated by lack of funds. Suppose, for example, a certain conversion scheme can be tested for around $100,000. An industrial concern would probably not proceed unless a 25 percent contingency were added and there was at least double the "guesstimated" amount in the "kitty." The Office of Saline Water has perforce to operate the other way round. Instead of $100,000, only $70,000 can be found. Through the bed of motives, patriotic, scientific, and personal, all parties, inventor, contracting firm, and Government agree to try to live within the inadequate budget with the understanding that—"if it begins to look good, we can apply for more." Soon the money does run out, perhaps so swiftly that no one is aware the budget has been exceeded. Comes a sudden halt, examination by accountants, and application for new funds. These eventually come through—at 70 percent the safe amount. End result, the project takes double the minimum time and costs more than an initially well-heeled appropriation would have done. Note, that everybody connected therewith has acted unselfishly and in impeccable good faith. It is the pattern, not the people that is at fault.

What, then, should be the pattern? Choose a project, have continued faith in it, endow it adequately in advance and delegate its execution to the contractor.

There is much speculation today how the Soviet scientist has come to compare so favorably with our own. I do not believe the political systems or the comparative qualities of the individuals are involved. I suspect it is a matter of management; that the Russian scientist is deputized to bring his work to fruition himself; here there is a tendency for any person or agency who has "bought in" to an invention to know more and decide more by definition than the inventor himself. We should, I think, move away from such tendencies in our work on saline water conversion.

My formula for an expanded Office of Saline Water, if you will forgive the didactic brashness which characterizes these notes—through the privilege of your kind invitation to testify—my formula is:

More personnel
Delegation of detail management
More money
More autonomy for individual projects
Less evaluation, more will to proceed, and more followup.

### A CONCRETE PROGRAM

A basic preliminary, as suggested earlier, is a firming up of the Government's policy toward saline water conversion, whether it wishes to hold the reins or expedite transfer to other agencies; including the Armed Forces, conservation agencies and, of course, industry. The second choice seems almost inevitable and to aid in this, it might be useful for the Office of Saline Water to establish a public-relations section and a procedure for circulating technical information at the earliest practicable moment. A monthly house organ and periodic press releases would be most welcome.

As to projects for sponsorship, the following might merit consideration:

1. Construction of a large coupled water conversion plant to be integrated with the existing water distribution system of a large eastern coastal city. Example: stills coupled with Hell Gate powerhouse to operate on Hudson River tidal water for Manhattan Island.
2. Ditto for a western seaboard city in a water scarce area. Perennial example: San Diego.
3. Development of various types of mobile uncoupled converters for emergency and disaster use. Example: motorized equipment for the Red Cross.
4. Increased support in industrial and academic laboratories for improving phase barriers, i. e., surface elements where salt and water part company.
5. Development contracts for improved manifolding of phase barriers, e. g., finding out how to pack more surface more cheaply into unit space.
6. Surveying the potentialities of coupling low energy nuclear reactors with water-conversion devices.
7. Simultaneous development of various means of utilizing centrifugal phase barriers, wiped film, and falling film barriers.
8. Establishment of a Government saline water testing station where—
   (*a*) The Government's own tests may be carried out.
   (*b*) Persons or firms may apply to have their own units tested.
   (*c*) Persons or firms may be granted facilities for making their own tests.
   (*d*) Limited quantities of sea water may be shipped to laboratories for test purposes.

In conclusion, I readily admit that the expansion of activities suggested could absorb very large amounts of public funds. However, at a time when all kinds of excuses are being sought for public works to place money in circulation, I beg to submit that none could merit support better than saline-water conversion.

I have weighed very carefully the possibility that my remarks will be considered naive, grandiloquent, and perhaps entirely presumptuous, but I have concluded that you may prefer to have my positive thinking rather than inoffensive platitudes.

A paper recently prepared for presentation before the American Chemical Society entitled "Where Now in Saline Water Conversion" is offered in supplementary testimony.[1]

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[1] This paper is available in the subcommittee files.

TABLE I.—*United States water incidence and usage*

[Total land ,area, less lakes, etc., 2,975,000 square miles]

| | 1 | | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | (*a*) Billion acre-feet per year | (*b*) Trillion gallons per day | Billion gallons per day | Million gallons per day | Thousand gallons per day | Gallons per day |
| Natural water: | | | | | | |
| A. Precipitation | 4.7 | 4.4 | | | | |
| B. Runoff | 1.3 | 1.2 | | | | |
| C. Net catch | 3.4 | 3.2 | | | | |
| D. Farms, pasture | 1.1 | 1.0 | | | | |
| E. Forests, scrub, etc | .75 | .68 | | | | |
| F. Useless land | 1.55 | 1.40 | | | | |
| Diverted or processed water: | | | | | | |
| G. Irrigation | .111 | .100 | 100 | | | |
| H. Industrial, power, etc | .111 | .100 | 100 | | | |
| I. Municipal, domestic | .014 | .012 | 12 | | | |
| J. Greater New York City, approximate | | .002 | 2 | 2,000 | | |
| K. Greater Los Angeles, approximate | | .002 | 2 | 2,000 | | |
| L. All other cities and regions | | .008 | 8 | | | |
| M. Average family | | | | | 0.375 | 375 |
| N. Indirect | | | | | | 200 |
| O. Direct | | | | | | 175 |
| P. Average person | | | | | | 75 |
| Q. Indirect | | | | | | 40 |
| R. Direct | | | | | | 35 |
| S. Conversion, saline water: World usage | | | | 12 | | |

## STATEMENT OF DR. KENNETH HICKMAN, CHEMICAL ENGINEER, ROCHESTER, N. Y.

Dr. HICKMAN. It is a great pleasure to be here, sir.

My background is that I have been for many years a photographic chemist and have gone from photographic chemistry to the distillation vitamins, production of vacuum stills, vacuum pumps, etc. I might describe myself as an independent project engineer. By project engineer, I mean that a subject comes to interest me and I begin to promote that subject until finally I am engaged entirely on that project.

I am engaged at the moment on the project of converting any kind of unpotable water to potable water. Now, when I received the invitation to testify here, I hadn't any idea of what was required of me and I took a chance by assuming that the technical data connected with my process has been covered in a number of Government reports and I would therefore rather like to speak on the overall picture of how we are going to solve this problem, and I crave your indulgence whilst I deal with that.

I have noted wherever I have been—and I have just come from a salt-water symposium held in San Francisco the day before yesterday—that nobody is quite sure what the objective is. One of the stated objectives is to produce converted water at less than $100 an acre-foot. About the time I was considering this, the organization called Resources for the Future came out with some very good figures

for the various water usages in the United States; and I tried to put these on a logarithmic chart but my chart became nine log stages long. So I decided to use neighboring columns, not multiplying by 10 but by 1,000 per column, which produced the table which follows my written statement. (See p. 200.) The table shows that of the 4 trillion gallons a day of rain that were falling on the United States, 1 trillion only gets to any kind of use by man, animal, or plant, about 100 million go to agriculture by irrigation, 100 million into industry——

Mr. JONES. Will you start over again where you stated about the use of this water?

Dr. HICKMAN. Very good, sir. I found from Dr. Löf's figures from the Resources for the Future that we have 4.4 trillion gallons a day of rain and snow falling on the continental United States. It is an interesting correlation. You see, there are 325,000 gallons in an acre-foot. There are 365 days in a year. So as a rough approximation, an acre-foot per year is 1,000 gallons a day, and we can transpose them readily. So this 4.4 trillion gallons a day is about 4 billion acre-feet a year. Of this, only 1 trillion gallons gets into that part of the earth where things are planted and people are living. Of that 1 trillion, about 100 billion, or 10 percent, are rerouted by irrigation works, and so forth, to extend agriculture. About 100 billion go to all possible industrial uses. This 100 billion is a very loose figure because it includes the sort of water that is taken in from a river to cool a power-plant and immediately put back in the river again. Sure! It's been used, but it hasn't in any sense been lost; and it is going to be used over again many times. Then I find that the total amount that goes to human use—that is, supplied by different waterworks organizations and is pumped up in somebody's backyard from a well or is taken by industry from wells, etc.—is about 12 billion gallons a day. Metropolitan New York City, Manhattan Island, uses about a billion gallons a day; and Greater New York, 2 billion. Greater Los Angeles, 2 billion; Metropolitan Los Angeles, 1 billion. Then we come down to the family using on an average 375 gallons a day.

Now, the purpose of bringing those very well known figures before you is simply to suggest that there isn't one solution to this problem at all. We have this enormous size spectrum and what we are going to do to supply one size of user will be entirely different from what we do for another. By making too much play about the needs of a particular cross section of user, we are liable to obscure the needs of the other sections and perhaps discourage efforts to work in those other regions. And I will maintain there are just as many important and useful things to be done with many, many small conversion units as there are with the big plants. I am going to deal with that specifically in a minute. So much then for this size spectrum.

The next question I ask myself is, Do we really want converted water? As I read the Scientific American, the syndicated magazines, the daily newspapers, I find the most extraordinary sums of money being devoted for the most extraordinary purposes. For instance, if we in the United States have accelerated an electron to half a billion electron volts and it is suddenly realized that Russia has accelerated an electron to three-quarters of a billion electron volts, immediately half a billion dollars can be found for us to set up a

particle "racetrack" somewhere to make an electron go still faster. Again, I don't have to remind you of the amounts of money being spent on space satellites. Only the other day, I saw a long article, quoting distinguished scientists as saying that for the very reasonable sum of $2 billion we can land a man on the moon.

In contrast, I find this committee examining carefully whether we should have $1 million or three-quarters of a million or $875,000 annually for the purpose of converting sea water. And the first question that occurs to me is, "Do we really want converted sea water or are we discussing the matter with the idea of putting it in archives or a museum to do something about, some day or other?" Having asked that question rhetorically, I will now go back to a figure of $2 billion which is very interesting. It is your atom bomb cost, the cost of landing on the moon, it is the amount that has just been voted for a roads program. Now, presumably all those roads will lead somewhere. I don't know whether they do, but let's see where $2 billion would lead for water conversion right now. And, fortunately, I can adopt the figure developed this morning for sea water converted on a large scale, namely, $1 per 1,000 gallons. The capital cost for machinery to produce this kind of water by well-established means is at the present moment, using the Singmaster & Breyer figures, about $3.50 per gallon day of capacity. So, for $1.8 or $2 billion for our roads program, we could get a supply of 600 million gallons a day, which could be fed into the water supply for metropolitan New York and would add 60 percent to or replace 60 percent of, the existing supply.

Now, if you will examine the aqueduct systems that have been brought down to New York City, you will find that most of the resources of a large valley leading up the Hudson to Connecticut was tapped in 1832; then in 1907, the engineers had to go to the Catskills and Pepacton Reservoir.

If we view the picture of New York-New Jersey against the surrounding watersheds, we can see that the growth of the population centers is now so great there isn't anywhere in the neighborhood to tap for more water. In fact, the cost of bringing aquaduct water into New York is probably more now than it would cost to install water conversion machinery, whether these would be of the well-tested variety installed in the Caribbean, or of the "newer conventional" type proposed by Dr. Badger.

I suggest, therefore, that the so-called manufactured water could compete very nicely with new natural water in this location; but there is much more to it than that. In the event of national disaster, I cannot think what would happen to existing water supplies, aqueducts, reservoirs, and so forth; if we had water conversion plants, they could not all be knocked out at the same time, and within an hour, they would start producing usable water. How pure would the water be? Well, it would have contaminants reduced by a factor of 50,000; and if the distillation capacity was halved in an emergency, in order to double distill, the contaminants would be diluted 250 billion times, so that we should have an ample margin of safety.

Now, I'm not for 1 minute advocating a $2 billion program but I am advocating an integrated pilot-plant program. If the problem were to make a motor car, or an intercontinental ballistic missile, I don't think we would be content with having produced one, launched

one, and say, "Well, that's fine. We now have our plans. In the event we need cars or there is a war, we can go into manufacture." The motor car and the missile, as we know them today, have reached their usefulness only by getting into regular production, making better models year by year and eliminating the bugs in the earlier model. The task before us, I believe, is to get a succession of small conversion devices into the hands of individual users; and get bigger and better large plants on a regular service basis—not to distribute distilled sea water as such but to blend this water with existing municipal supplies, so the customer need not know whether he is getting distilled or river water or any other kind of water; and in this way, we shall find out just what is involved in launching out into the business of converting water.

This brings me now to my next question, and that is "coupled plants." It has been assumed here that we all understand exactly what "coupling" means, in this particular context, but actually I think in a sense it is so revolutionary that it should be discussed a little bit.

The absolute minimum amount of energy needed to separate salt from sea water by Mr. Maxwell's traditional "demon" is 1 British thermal unit per pound of fresh water produced. But to separate this salt by simple distillation takes a thousand units, so we use a thousand times more heat when we use a single still then we ought to if we really knew how. In conventional multistage stills, we achieve 4 to 5 effects and in Dr. Badger's proposed equipment, we hope to get 9 effects, so we shall then use 111 units of heat instead of the theoretical 1. About 30 years ago, it occurred to the engineers that if they were to take most of the energy out of the steam in a powerplant first, and then use the exhaust steam for distilling water, they could supply the distillate more cheaply because they could sell the electricity. Thus, was born the important concept of coupling.

Water conversion has been cheapened by this means, to the surprise of everybody, almost down to the dollar level. The diminution in costs has come from two places: One, the act of coupling. If you want to see what that means, the bringing of the powerplant to the water converter is like bringing a drawer full of big marbles to a drawer full of little marbles, and mixing the two. The marbles now occupy only a drawer and a half because the little ones have been able to fit in the cracks of the big ones.

The second cost contraction comes from the fact that engineering firms have been in the business of supplying distillation equipment for 25 years and have found out how to cheapen the process. Each new plant has been cheaper and better than the one before.

The third cost contraction, desired for the future, can only come from altering the marbles—that is, the basic separation processes—themselves. If we could have suddenly an invention which would give us a 10 to 1 advantage in separating salt from water, could put that invention lock, stock, and barrel into any 1 of these coupled situations, just take out what is there already, and put in the new invention.

The point I want to make clear here is that the great advance that has come from coupling is an advance of the past; the next great advance must come, I think, from proceeding with fundamental work and new inventions.

Now, if I may pass, sir, to other parts of my notes, and discuss how we are going to support the development of new inventions in water conversion, I should like to begin by expressing, as I have done in my written transcript, a very high regard for the work of the Office of Saline Water. It has acted as a nucleus, a focus to bring in knowledge from all parts of the world and to disseminate knowledge to all parts of the world. It has promoted a number of processes and has also had to keep, politically speaking, a great number of people happy, which it has done very well. But if they are to get somewhere further, I think very much larger funds must be made available; and I respectfully suggest that those funds be disbursed in a slightly different manner than in the past.

Obviously the personnel of the Office of Saline Water is spread very thin at the present time, and I would like to recommend that an executive director be added to the staff to deal with the 101 detail problems that are always demanding immediate attention, whilst main policy problems are left to the Director. As to monetary support, I'd like to see present funds multiplied by 10, as a minimum; and for the support of individually sponsored projects, could there not be more financial backing and more autonomy given to the people directing the projects. No worthwhile invention can be brought to successful completion by a committee of administrators on one side and a committee of evaluators on the other side. You have to have, at the start, a burning conviction that what you're doing will be successful, and you have to be allowed to proceed in your own way to your objective; the price for this operating freedom is that you must be held responsible for any failure at the finish. So I would like to see more autonomy for individual projects, less evaluation, more will to proceed, and more followup.

Now, I have purposely left out of my testimony——

Mr. JONES. At that point, by "less evaluation," you mean evaluating the work for progress or evaluating it for the purpose of determining whether it is economically feasible or not?

Dr. HICKMAN. I think that the economic feasibility is best determined in very general terms at the start. The evaluation that I was referring to was evaluation as to the progress that was being made with the device. I feel that when once you have started on a program, the thing to do is try to bring it to completion and then evaluate it at completion, rather than in the interim stages.

Mr. JONES. Go ahead. Thank you very much.

Dr. HICKMAN. I left out from my written testimony any reference to my own project that has been sponsored by the Government, and I don't know whether you would care for me to comment on the position that that is in at the moment, or what I think about it.

Mr. JONES. Yes, indeed. Yes, sir.

Dr. HICKMAN. In any kind of a still, the heat has to be put into the water, then it has to find its way to the surface of the water to cause evaporation, and the steam has to be taken off the surface.

In conventional equipment, as I have observed it, that is a fairly long path, offering resistance to the process; and it occurred to me some 5 or 6 years ago that we could take a technique that we knew of in other regions, the spinning-plate technique, in which we would put sea water or dirty water of any kind on one side of a rotating disk of very

highly conducting metal, spin the water across the disk, detach the steam—because the steam is spontaneously present there at any temperature—bring the steam around to the back of the disk at slightly higher pressure, condense it there and fling the water off on the other side.

When this idea was put into test operation through courtesy of Mr. G. D. Dickerson, the first time in 1952, it gave factors—generally known as $U$, the total heat transfer coefficient—of somewhere in the region of 2,500 units per square foot of surface, and the figure that was being realized in conventional equipment at that time was about 600 to 800, with 650 being the average when the equipment was clean.

In other words, we had a 4 to 1 advantage in the first experiment. In later experiments we realized figures of some 3,000 and 4,000. At that time two decisions were made. A decision was made by the Department of Saline Water, liberally urged by myself, I might say, to build a large plant now known as the No. 5 still, with rated capacity of 25,000 gallons a day. That's the one at Harbor Island. Then, there was a private decision to go ahead commercially and build a very small still about the size of one of these chairs here, which should produce somewhere between 400 and 600 gallons a day of water from any given source of water.

In other words, if Mr. John Doe acquired one of these stills, he can take the tailpipe and put it into the ocean or into a well or into a pond in his backyard or into a ditch of saline water that is running by, and produce potable water.

One can do research very much faster on a small unit than a large, and the small one which was started a year ago is now complete and is approximately ready for manufacture. It produces the 500 gallons a day from sea water with a present experimental cost overall usage of electricity, electric power, of 80 kilowatt-hours per thousand gallons. I don't speak of costs here because the costing of a domestic unit is completely different from a public utility. You have no housing, no labor, nor the charges that ordinarily go into a municipal plant. You simply pay for your power and attend to the still yourself.

The large still is running at Harbor Island at the present moment, I believe, turning out water for somewhere between 50 and 60 kilowatt-hours per thousand gallons but we—that is, the Battelle Memorial Institute and myself—have much more research work to do and I am confident that if we can complete our experiments on this still and can proceed to build a succession of other stills with the experience gained from this one, that we can devise a very economical distillation machine.

Now, my concluding sentences are as follows: It has been suggested that because our evaporator rotates that it must necessarily be expensive. That is far from the truth. In our little still, we have 6 of these rotating plates nested in a sandwich 4 inches thick and 2 feet in diameter. It rotates about 1,400 revolutions a minute on a central shaft; and the question has been put to me, suppose we could get equally high transfer coefficients on stationary surfaces, wouldn't it be much cheaper to have the 6 plates standing on 4 legs instead of turning around? And the answer is that when it turns around, it stands on 1 leg; and when it stands still, it requires 3 or 4 legs, and it is not any more expensive to make it rotate. That is not the problem. The problem is,

How do you pack a whole lot of these surfaces economically into a given space?

I have every hope that in this expanded program that I am advocating, that at least I will have an opportunity of sharing in it in some small way. Perhaps I might say just one other thing, sir, before closing, and that is: I am wondering whether it is clear in everybody's mind just how far the Government wishes to participate in these programs and I would assume that the objective of the Office of Saline Water and the Government at large is to nurse these programs only until they can be transferred to industry, and with that in mind, I would recommend the rapid dissemintaion of news and information among all contractors about all processes that are being worked on.

Thank you.

Mr. JONES. Thank you very much, Dr. Hickman.

Are there any questions?

Mr. DAWSON. Thank you; no.

Mr. JONES. Again, thank you, sir. It's been a pleasure to have you and your testimony is quite valuable, I assure you.

All of the witnesses scheduled today have not been heard. We will expect to hear you this afternoon. We had not scheduled a hearing for this afternoon, but we want to have your testimony, so the subcommittee will stand at recess until 2 o'clock.

(Whereupon, at 12: 17 p. m., the subcommittee recessed to reconvene at 2 p. m., Thursday, April 17, 1958.)

AFTERNOON SESSION

Mr. JONES. The subcommittee will be in order.

Dr. John Geyer, chairman of the department of sanitary engineering, the Johns Hopkins University, will you please come around to this side.

Do you have a prepared statement, sir?

Dr. GEYER. I prepared, with Dr. Abel Wolman, a statement which we mailed here some weeks ago.

Mr. JONES. Then we have the statement prepared by you and Dr. Wolman, and it will be made part of the record. Would you like to brief us and bring out the important points of your paper?

Dr. GEYER. It is quite short. It will probably take me about 5 minutes to read it. Then you can ask me anything about it you would like.

## STATEMENT OF DR. JOHN C. GEYER, CHAIRMAN, DEPARTMENT OF SANITARY ENGINEERING, THE JOHNS HOPKINS UNIVERSITY

Dr. GEYER. The conversion and use of saline water is and will continue to be relatively expensive for a variety of reasons. First, saline waters are low-elevation waters which must be lifted to the place where needed. Second, the energy liberated when the salts are originally dissolved in a saline water must be returned to the water in order to again separate these salts. These requirements for pumping to a usable elevation and for replacing the heat of solution of the salt present irreducible energy requirements. Furthermore, any type of saline-water conversion system probably will involve the use of equipment that is relatively expensive to construct, operate, and maintain.

Since the monetary value of water is established by the cost of the least expensive adequate source of supply, saline water conversion, to be practical and relatively competitive, must afford a cheaper water supply than any other alternative source.

The cost of developing a supply from a natural fresh-water source involves the following expenses: (1) Transportation to the area where needed, (2) lifting to the elevation at which the water is needed, (3) storing till the time when needed, and (4) distribution to the consumer who uses the water. Purification constitutes an added expense of relatively minor nature, particularly when compared with the cost of desalting a saline water. In any event, only a small fraction of the fresh water used in this country requires even moderately costly purification.

Since a converted saline-water supply would ordinarily require at least as great an expenditure for storage, pumping, and distribution as would a fresh-water supply, the cost of desalting a saline water must, therefore, generally be balanced against a reduction in the cost of transporting fresh water to the area where the supply is needed.

The unit cost of transporting water declines more rapidly with increasing quantities handled than does the unit cost of desalting saline waters. For example, if one considers the quantities of water required for a large irrigation development, comparison of transportation costs with the most optimistic guesses as to the lowest attainable cost for desalting indicates that it would be more economical to transport a natural fresh water several thousand miles overland by pipeline, tunnel, and open channel than it would be to convert ocean water to fresh water. Thus, it is inconceivable that desalted ocean water will be extensively used for irrigation on the North American continent for many years, if ever.

In the above connection, it might be pointed out that the use of fresh-water resources of the United States is very small, indeed. In Maryland, for example, 94 percent of the annual supply runs into the sea without having been removed from the streams for any use. Of the 6 percent removed for use, almost all is returned. In general, the so-called water shortage is nothing more than a shortage of cheap water. Only that very small part of the total fresh-water supply which is naturally available at the right time and the right place is being exhausted. Storage and transportation facilities are needed in order to make available the tremendous volumes of fresh water that are now wasted to the sea.

Because of the above situation, the conversion of saline water will be used only for relatively small supplies, where the need for water is urgent, energy is cheap, and the cost of transportation is excessive. Drinking and domestic supplies and the very-high-value industrial supplies in desert areas and on the desert islands of the world are now occasionally obtained by the conversion of saline waters. As the cost of conversion comes down, such supplies will multiply in number. It is quite likely that a small, domestic conversion unit can be developed which will be in the same cost range as the usual home air-conditioning and heating plant. Reliable and cheap domestic conversion units may someday be extensively used in oceanside dwellings and in areas where surface waters are absent and the natural ground waters are too saline for domestic use.

In areas like Saudi Arabia, the central Sahara, the west coast of South America, and the Virgin Islands, larger conversion units will be economical. In cases where fresh vegetables must be flown in at great expense, converted saline water may even be used in some cases for growing special foods.

It is, therefore, considered that the research now being carried on under the Federal saline-water conversion program is highly useful, even though the current public hopes for spectacular results may never be realized. In general, the developments which will be made should prove most useful in areas outside the United States, but, since much of the equipment will be manufactured in this country, research in the field of saline-water conversion will benefit American industry.

The rest of this statement deals with the specific questions asked in your letter. Should I refer back to each of those in this connection, sir?

Mr. JONES. I believe I would.

Dr. GEYER. The first question was with regard to the current state of progress, both here and abroad, in saline-water conversion. In our opinion, the progress in saline-water conversion is reasonably rapid. The translation of laboratory results through pilot-plant studies into large-plant-scale operation could be accelerated.

Item 2 was the extent of coordination between various governmental and private groups, both here and abroad. That has been very good, and has been improving rapidly, particularly as a result of the seminars which the Office of Saline Water has held, and other such activities.

The third item is whether the rate of progress ought to be accelerated, and I will read our statement on that.

The rate of progress might well be accelerated. The direction of acceleration, however, should be on a selective basis. The Advisory Committee to the Department of the Interior should be served by a technical staff that can assist in the selection of the most needed research and the most promising processes for development. In order to do this, the technical staff should be provided the necessary travel funds to (1) visit and review, in person, current research; (2) follow up leads and ideas which might be useful; (3) encourage initiation of research in promising areas; and (4) seek ideas and information in the various basic and technical sciences which could be applied to this problem.

The fourth matter dealt with what particular steps might advantageously be taken by the Government to encourage acceleration, and, with regard to this, we have said that, since scientists in general are not particularly interested in equipment development or pilot-plant studies, they have not often, of their own volition, concerned themselves with this program to the point of participation. A more concerted effort in the form of visits to scientific establishments and a more active program of encouragement and assistance in the development of ideas and research projects might accelerate progress. Modest budget increases should be made available to support the field activities of the Office of Saline Water and permit it to search for ideas and stimulate work. The Office should also assume the responsibility for deciding when pilot-plant and, occasionally, full-scale plant tests are

warranted, and should provide the means, the stimulation, and the necessary review and inspection for trial plants.

The final item dealt with various processes under investigation and development, including, to the extent available, data on the conversion cost estimates, quantity of water converted per day, and the source of saline water before and after treatment.

To this we have said that the evaluation of processes so far studied has become more realistic. However, mixing of propaganda with realistic evaluation still leaves something to be desired insofar as a public understanding of the work is concerned. Such a mixture is not conducive to the best scientific results, nor to an active interest on the part of many qualified scientists, although it seems to have been thought necessary in order to establish a basis for continuing the investigation.

In this connection, I might say that in all the literature on the cost of desalting water which I have seen, as compared to the cost which the consumer pays for it, one figure very frequently seen is a figure of 30 cents per thousand gallons. To compare the cost of desalting water with this 30 cents per thousand gallons is like comparing the cost of power production with the cost which the consumer pays for power. In the power field, electricity can be produced usually for from 5 to 7 mills per kilowatt-hour, and it is sold to the consumer at figures ranging from 10 to 50 mills per kilowatt-hour. The water field is quite analogous to this. The cost of producing water at the center of the area where you want to distribute it is usually in the range of 5 to 7 cents per thousand gallons, and the cost to the consumer is usually in the range of 10 to 50 cents per thousand gallons. This, of course, is because the distribution costs are by far the largest part of the expense, and the 30 cents usually quoted includes those distribution costs. So that a fair comparison could be made if the value you used for water as it costs now were something like 5 or 7 cents per thousand gallons, because all the desalting process does is produce water in the area where it is needed, and it must be then distributed and sold.

Our final paragraph concerns this whole field of activity. The amount of Federal money spent on this program has been quite modest in relation to the importance of the work. When compared with the investment in research on such things as missiles, airplanes and the like, the cost is hardly visible. Although additional support for a more active field program on the part of a highly qualified technical staff and for building a few carefully selected and located pilot and small-scale plants is desirable, there seems to be no need for greatly expanding the Federal budget for research and development in the field of saline water conversion.

We think the work is very useful and that it by all means should be continued, but that at the same time it would be desirable for the public to realize the economic facts of life in this business a little better than they do now through the current type of releases in magazines.

Mr. JONES. I notice that you are chairman of the department of sanitary engineering of Johns Hopkins University.

Dr. GEYER. That is right, sir.

Mr. JONES. That is an unusual activity of a university, is it not?

Dr. GEYER. All departments of civil engineering and engineering colleges teach at least 1 or 2 basic courses in the field of sanitary engineering. Eight or 10 of the universities have specialized departments, as ours does.

Mr. JONES. How many universities give degrees in sanitary engineering? Are there very many?

Dr. GEYER. Universities seldom call the degree a degree in sanitary engineering. It is either civil engineering or just a master's degree or doctor's degree in engineering. But schools like Harvard, Michigan, Minnesota, California, and Johns Hopkins and quite a few others are now training men for this field of work.

Mr. JONES. I notice your observation is one of a general character that to conserve and properly utilize the amount of rainfall we have at the present time, we are not moving ahead as fast as we should in that area.

Dr. GEYER. I do not believe the situation is quite as critical as some people think it is. But sometimes the rate of progress is pretty slow. It takes a very long time to develop these water systems. New York City, for example, planned to go to the Delaware River for additional water in 1923, and due to the controversies with New Jersey and Pennsylvania, primarily, the very long court hearings held, it got up into the depression before they were given the right to go ahead.

Mr. JONES. Did you ever hear of "Incodel"? [1]

Dr. GEYER. Yes. I know the men there very well.

Mr. JONES. How long has that been in existence?

Dr. GEYER. It has been in existence some time.

Mr. JONES. Since 1936, has it not?

Dr. GEYER. Right.

Mr. JONES. They have not built a dam or spent a dollar, have they?

Dr. GEYER. No, sir.

Mr. JONES. Still meeting and talking about it?

Dr. GEYER. Well, this is generally true of most of the interbasin committees. They are not given any authority, and they have no money.

Mr. JONES. Do you know of other interstate compacts that are now outstanding where there is any work being done to utilize the water resources throughout the country? Are you familiar with the New England interstate water-pollution-control compact?

Dr. GEYER. I know of the Tri-State Compact between New York, Connecticut, and New Jersey. That is also on pollution. They have done a little work in the control of pollution or setting up standards. I have worked for the Interstate Commission on the Potomac River Basin under the Potomac River Basin compact.

Mr. JONES. They have published statements on just about every post you come to; have they not?

Dr. GEYER. Yes.

Mr. JONES. There is no authority for enforcement?

Dr. GEYER. None whatever. They have no money.

Mr. JONES. Just a seminar, some place to talk about it?

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[1] "Incodel" is the acronym for the Interstate Commission on the Delaware River Basin.

Dr. GEYER. That is right.

Mr. JONES. Let's look at the New England interstate compact. Do you know of any dollars they have spent except for meetings?

Dr. GEYER. These compacts do not have any dollars. The Interstate Commission on the Potomac River Basin operates on less than $100,000 a year.

Mr. JONES. To talk about it?

Dr. GEYER. To talk about it.

Mr. JONES. That is right. And you will notice that one of the things that these local papers talk about around here is that the Potomac River is a stream of national importance.

Dr. GEYER. It certainly is.

Mr. JONES. And every other stream throughout the country is a stream of pork barrel proposition. Have you ever noticed that?

Dr. GEYER. Well, I can comment on that, but I do not think I should.

Mr. JONES. Do you know of any field of Federal investment where the returns have been any greater than those investments made in water resources for our people?

Dr. GEYER. No, sir, I do not, especially when they have been done as has been the case in the Tennessee Valley Authority, where they took into account all the uses and developed a complete plan.

Mr. JONES. The only way we use the Tennessee Valley Authority today is for export. We do not believe in using it in this country, but we will finance some foreign country to build one exactly like it. It is acknowledged as being the best river development in the entire world, in all history. Yet do you think that the people of the country would support another TVA, partcularly on the Delaware River at Philadelphia, where just a few years ago the water was unfit was almost any type of use?

Dr. GEYER. I do not believe that they would support another setup that is politically, financially, and administratively like the TVA.

Mr. JONES. No; because it has done too good a job. That is the only reason. That is the only mistake the TVA has ever had. It has been so entirely successful. They are not going to have to worry about water for the next 50 years at least, and I do not know of any other section that is going to be that fortunate. But it ties in with the whole proposition as I sense it. Either we are going to attack these water problems on a broad front to get the widest and most prudent use of it and the use of the money invested in it, or we are going to have a very, very expensive proposition on our hands in 50 years.

The water problems of the city of New York were discussed this morning by one of our fine witnesses, Dr. Hickman. There was not any planning in the city of New York, so they are going to the upper reaches of the Delaware River and having to construct at great cost their own reservoir.

Now, why are you of the opinion that we do not need to expand the basic research program of desalting?

Dr. GEYER. Well, they are studying, so far as I know, about every possible means that can be thought of to desalt water, and it seems to me that the progress in this field is as good as can be expected.

Mr. JONES. They spent only $25,000 out of a total of $825,000 appropriated for the operation of that Office last year for research.

Dr. GEYER. I have understood that.

Mr. JONES. That does not seem like a very bold and ambitious program, does it?

Dr. GEYER. I do not believe that the program can be stimulated much unless the staff is increased and has an opportunity to go out and stimulate interest in the field and help people in the field get work underway. As I understand it, they wait for somebody on the outside to decide they would like to work in this field and write in to them, and the man on the outside, who is very busy to begin with, with a great many other things, is usually not very apt to get into this, particularly in recognition of the fact that he understands that this is going to be an expensive proposition, that desalting is never going to be on the grand scale that the public or some of the public have been led to believe is possible. But it is an area of activity where, by research and development, the costs can be brought down some and equipment improved some.

Mr. JONES. Are most of the municipal distribution systems owned by the municipalities or by utilities?

Dr. GEYER. I think over 90 percent of them are owned by municipalities. Certainly 95 percent of the water is sold through the municipally owned systems. There are a lot of little systems that are privately owned, so numberwise the percentage of privately owned systems is much greater than quantitywise on the basis of amounts of water sold.

Mr. JONES. And the cost of those distribution systems, the cost of the water, is in the monthly rates, whatever they are, just the actual cost and no profit?

Dr. GEYER. Well, that varies quite widely. The system with which I am most familiar is that at Baltimore, and in most years in the past they have returned to the city general funds something on the order of $1 million a year. There are other cases where the reverse may be true and they may be subsidizing the water out of the general tax.

Mr. JONES. So if progress is made here it will inure to the people throughout the country generally, and nobody is going to put the profits from this program in their pockets?

Dr. GEYER. That is right.

Mr. JONES. So that should give us added concern to think that it is research and development work that falls within the realm of proper Federal responsibility?

Dr. GEYER. I think so, just the way that the research on aerodynamics down at Langley Field does. This is the same kind of thing.

Mr. JONES. Would you like to take on a project of research at Johns Hopkins for the Department?

Dr. GEYER. We toyed with an interesting idea and sent it in, but we have not pursued it any because it requires considerable work on our part. Although it is an interesting idea, we have not had the time to do the background work and to make the preliminary estimates to see just what might be the potential of it.

Our idea was that we would take the moisture out of air, in just the way that it rains when the air goes over a mountain, by reducing the pressure let it precipitate and then recompress the air to get it out of the system. We would have a snow machine, you see, which would get water, but the air coming out would have all the latent heat of vaporization of that water in the air, and we could start accumulating

some heat to use. I have no idea whether such a thing could ever be made practical because of the low pressures of operation and other factors, but it might be something interesting to get into. Here is a case, though, where we would be a lot more apt to do something about this if we had more stimulation and help from the Office of Saline Water. We are all so busy, that we stick this idea in a folder and put it in the file case, and if we do not have anything to do some day we will pull it out and play with it.

Mr. JONES. Are there some areas in California where the cost of transporting water is so very high that the price of desalting water could be competitive with transporting it?

Dr. GEYER. Frankly, I do not believe there are such areas. The cost of transporting water is exceedingly cheap when you handle large volumes, and I figured out how much it would be, based on California figures, for transportation. I came up with a figure of between 5,000 and 10,000 miles as the distance they could afford to go for water. I did not believe it myself so I had some of my students and men around the Department check this, and that is how it comes out. They can come back to the Susquehanna River cheaper than they can convert ocean water.

Mr. JONES. Any further questions? Thank you very much, Dr. Geyer.

The next witness is Dr. H. P. Gregor, professor of chemistry, Polytechnic Institute of Brooklyn.

## STATEMENT OF DR. H. P. GREGOR, PROFESSOR OF CHEMISTRY, POLYTECHNIC INSTITUTE OF BROOKLYN

Mr. JONES. Do you have a prepared statement, sir?

Dr. GREGOR. Yes. I sent one in to this office a few days ago.

Mr. JONES. Would you like to summarize your statement for us and point out the important parts of it? Your statement will be made a part of the record, sir.

(The prepared statement of Dr. Gregor is as follows:)

STATEMENT OF DR. H. P. GREGOR, PROFESSOR OF CHEMISTRY, POLYTECHNIC INSTITUTE OF BROOKLYN

The Office of Saline Water has sponsored research in new processes and in the development of existing ones for the desalting of saline waters. At the present time, there are no more new ideas. Only three of the known processes appear to warrant further development. These are the distillation process, the freezing process, and the membrane process.

There are, actually, two water-conversion problems which face us today—that of converting sea water and that of converting brackish water. Brackish water has only about one-tenth the salt content of sea water, and, thus, constitutes a less difficult problem. Brackish water is present in many parts of the United States as both surface and underground water. These areas are usually areas of acute potable-water shortages, so there is no problem of pumping water over considerable distances.

The distillation process calls for vaporizing all of the water, which means its volume must be increased at least 1,500 times, and then condensing it so as to reuse as much of the heat as possible. The freezing process, on the other hand, calls for freezing all of the water, separating the relatively pure ice, washing it free of adhering salt solution, also conserving as much of the heat energy as possible. The membrane process, also known as the electrodialytic process, is, intrinsically, the most simple one. It consists in setting up a stack or sandwich of plastic membranes, passing the water to be desalted between the plastic films while an electric current is passed through the stack. The current re-

moves the salt from the water and concentrates it in alternate layers in the stack.

The electrodialytic process is unique in that it removes the salt from the water, rather than the water from the sale. For example, sea water is a solution of about 3 grams of salt in 100 grams of water. For brackish water, the corresponding figures are 3 parts per 1,000 by weight. The membrane process removes this small volume of salt from the much larger volume of water. It is evident that the membrane equipment will be smaller in size and less complex than comparable equipment for the other processes.

The principal problem now is to develop one or more of these processes to the limits of practicality, and to obtain reliable costs for power, fuel, equipment, maintenance, etc. The theoretical minimum power requirements are very low. In terms of electrical power, one can theoretically convert 1,000 gallons of sea water to pure water for about 3 cents, and 1,000 gallons of brackish water to pure water for only 0.3 cent. In practice, a total cost of 30 cents per 1,000 gallons would be allowable, but no process for sea water appears to be within striking distance of this figure today.

The membrane process does appear to be practical for the conversion of brackish water. I estimate that one can convert a typical brackish water to a potable level (4,000 parts per million down to 250 parts per million) for not more than 21 cents per 1,000 gallons, when considering a large installation which will serve a town or city. This estimate was arrived at by the realistic cost-estimate formula developed by the Office of Saline Water, and includes all components, maintenance, power, amortization, etc. The only cost not included is the development cost itself.

A small electrodialytic appliance could service a home or a farm from a brackish-water source or from the ocean. In these cases, the costs would have to be higher than for a large installation, but would compare favorably with the cost of transporting water or running pipelines over considerable distances.

The membrane process may also be practical for the conversion of sea water, but it would seem unwise to pursue this problem until the more simple one of converting brackish water is solved.

The Office of Saline Water has been encouraging all possible coordination in the saline-water field. It has been sponsoring research and development to the extent its budget allows. It has disseminated information and facilitated the exchange of information. Its own program has been hampered by a shortage of technical personnel within its own organization, presumably because its administrative budget is too low.

The research and development budget of the Office of Saline Water has been such that its efforts in sponsored research and development have been spread too thin. This entire field, in spite of its importance, has not been the subject of extensive research and development by private companies, except in a few areas. The market is too uncertain, and development costs too high. Accordingly, most organizations have looked to the Government for technical information in this field. Foreign groups have been generally unwilling to give or sell their know-how in usable form.

I propose that the Office of Saline Water concentrate in a limited area for the purpose of achieving a single objective. The membrane process is, undoubtedly, the practical one for brackish-water conversion. I propose that the Office of Saline Water enter into a program of electrodialytic cell development, with a physical-chemical contractor evaluating all available membranes and carrying out laboratory experiments, and an engineering contractor working on the design and fabrication of a pilot plant of suitable size so that reliable cost data for large plants can be obtained. I believe that this work should be carried out by agencies or organizations which will make the data freely available to all possible users.

Dr. GREGOR. I wonder if I could start, possibly, by showing you what some of these membranes look like, because I am a membrane man. I would like to explain that there are two kinds of membranes that I brought along with me. The ones that you can see through are permeable only to the cations, that is, to sodium, and these others are permeable only to anions. These are made from two fairly common polymers put together in a special way, and, of course, the hardware is also fairly simple. I had a high-school student that wanted

to do something for a science project, so I had him build one of these things. It is made out of plastic. The separators I got from England, because they happen to make this particular kind of fabrication. All you do is take one of these, lay a membrane on it, and you take another separator exactly the same, except you turn it 180°, and you lay another membrane on it and just keep building a stack. You pass the sea water or brackish water through one of these ports, and out of the other you will get the fresh water.

That is about all there is to it. Of course, the energy comes by passing an electric current down through the stack by electrodes at both ends.

Mr. JONES. How much current do you use, Doctor?

Dr. GREGOR. You can use as much as you want, of course, but you should try to keep the current density down below 10 milliamperes per square centimeter, because the process gets too inefficient. That is true of all thermodynamic processes. The faster you try to push it, the more inefficient it gets, so, the more slowly you can run it, the less it costs. This is, of course, well known.

The other thing I would like to show you is a picture in this book, which was written in 1931 by Prausnitz and Reitstoetter, entitled "Electrophoresis, Electro-osmosis, and Electrodialysis." It is a German book, and that is a picture of a membrane dialysis unit built by Siemens in Germany in 1921, and it looks not too different from the membranes which you might see today. By that I do not mean to say the problem was solved then, because in those days they did not have membranes. They used parchment membranes, which were not very good, and gave it up. Now we know more about polymers and plastics, and are able to make the films for the machines. We do need a lot of development on the machine itself, but, basically, this is not a new idea. You can go back to 1875, probably, and see that people have thought about this.

In answer to your specific question, I would like to elaborate on this, because I have heard some of the testimony today. Nobody has any new idea which is really revolutionary and which looks as if it is going to solve the problem immediately. I think the Office of Saline Water has certainly tried to find somebody that would tell them this, but, just as of today, nobody has a new idea that really looks good and that looks very cheap, at least for sea water. I think we have some processes which may work out for brackish water, but I think there are processes which will require development.

If you want to do long-term, basic research, of course, I am in favor of that, because that is my business, I guess. I think this, of course, is a sensible way to do it. But, again, what would you do it on? Well, I think that membranes could be made which now, I think, are perfectly feasible for brackish water. They are not good for sea water. I think they could be made good for sea water, but this is, again, a 2- or 3-year project, and when I proposed it to the Office of Saline Water they said, "We just don't have the money for everything." They said, "When you make a membrane which will let us have one ion and not the other—for example, the sodium ions are very bad for plants. The calcium does not bother them so much. Could you take out just the sodium?" I told them a year ago that I thought

you could not. Now, I have changed my mind. I think there is a new way to do it, but, again, this is a 2- or 3-year project to see if it will work at all.

I think there are many other proposals and ideas in about that state which are worth while looking into. But the question is: What is the Office of Saline Water supposed to do? At least, when I read the newspapers, and the Congressional Record once in a while, it seems that everybody wants them to come up with a process. That being the case, my feeling is that, if that is what they are supposed to do, I think they should concentrate now on a few areas where they have a fighting chance of coming through. I think for brackish water they certainly can do it, because we have already seen the Dutch and South Africans show us that we can do it. I think we can certainly do it in terms of brackish water. It is about one-tenth as concentrated as sea water. I think there is fairly good agreement that the membrane process is the only one that will do it.

Last fall, I evaluated the whole membrane area from the practical point of view, which I usually do not fool around with, but I did it for the Office of Saline Water, and I came up with a figure of 21 cents. But that is just for the conversion itself. For the hardware, for the cost of electricity, amortization, and all that, I used their formula. But that, of course, does not include any development cost and does not include any transportation cost. I think that these are realistic figures, because the process is not that complicated, as you can see. If a high-school student can put one together, I think, with suitable development, we can have a process in the country, but just for brackish water. Right now, this is not good for sea water. I think that, if you are talking about a small unit for a home or farm in an isolated area, for instance, this would be a very nice process for it, but the minute you go to a small unit or go to sea water, of course, the costs go way up and you have to decide whether it is worthwhile.

Now, I believe you asked me some questions about the way the Office of Saline Water operates. I think one of the difficulties in this field is that I am way over at one end doing research, theoretical work, in membranes in my field. I really do not have the vaguest idea of what the saline-water problem is out in the field, and, whenever I try to get these fellows to come down and spend a few days with me and orient me, they are much too busy. And I do not blame them. They have many other things to do.

I would like to see these fellows have a larger budget, because it encompasses such a wide area. I am a specialist in one small area, but I do not have the vaguest idea of what pumping costs are, Dr. Geyer's area, or anybody else's, and I think, really, to carry out work efficiently there should be good liaison. Of course, if you have just so much money, you have to decide where to put it. The figures I have seen from the people in the Rockefeller Foundation are that by 1975, if we do not start converting brackish water or sea water, we are going to have a food shortage. Again, I simply accept these figures. I know nothing about it, but 1975 really is not too far away in terms of long-range projects.

Mr. JONES. Doctor, do you have access to technical publications and translations of Russian scientific papers on this subject?

Dr. GREGOR. Well, of course, a good deal of the Russian literature is covered in chemical abstracts, but these are short abstracts. The major journals are translated, and I can get these translations quite easily. There are services for them. The trouble is the Russians publish in a whole variety of very obscure journals, and when I want one of the obscure journals this is usually impossible for me to obtain. I understand that the Russians take all of the American journals and translate them and make them freely available. I think we should do the same thing, because they have gotten into the membrane field, and I think they are going to do very good work in it. I would like to know more about it, but, right now, I cannot get the details because you have to read the primary source to really see what they are doing.

Mr. JONES. Do you have any information on what they are doing?

Dr. GREGOR. Well, of course, they did a fair amount of membrane work back in the 1920's and 1930's, because there was very close liaison with the Germans then. In the last 3 or 4 years, they have gone into membranes. The first papers, apparently, were rather crude, but they are going to come up, too, because their whole plastics field is developing. Their plastics technology is coming up, and maybe one of these days we will read they have an electrodialysis plant. I do not know if they need one or not, but, again, they certainly are moving rapidly in this area.

Mr. JONES. Do you have any idea how much money they are spending annually on this?

Dr. GREGOR. No; I do not have the vaguest idea what the Russians are spending. I can tell you the Dutch and South Africans, together, have had a total budget of, roughly, about $3 million or $4 million, United States equivalent, for just the membranes. Of course, they have concentrated on the membranes. They feel, for their purposes, the membrane is the best, because the South Africans, particularly, have a brackish-water problem. But that is a lot of money; certainly, much more than has been spent in this country.

Mr. JONES. How do the membranes manufactured by the Dutch and other foreign countries compare to the ones manufactured in this country?

Dr. GREGOR. No one has really evaluated them. You can look at the claims, and so forth, but the problem, really, is to see how they behave under the kind of conditions you have in a cell, whether they will stand up for a long time, because, if you are going to make brackish water potable with membranes, half of the cost of your water is the cost of the membrane alone. The stack is expensive, because you have to have lots of square feet of membranes in a stack.

I proposed in my memorandum to the Office of Saline Water that they evaluate all of these membranes very carefully.

You asked me if ours are better. I cannot tell you that, categorically, because I have never really examined theirs.

Mr. JONES. Do you know anything about the expenditure of $110,000 by the Israelis, money that we permitted them to use for a research program?

Dr. GREGOR. I was not aware that any funds were made available, sir. I do not know anything about it. I know they have been interested in membranes and are supposed to have a freezing process, but, as far as how it has been funded, I know nothing about it.

Mr. JONES. Mrs. Granahan?

Mrs. GRANAHAN. No questions.

Mr. JONES. Mr. Moss?

Mr. MOSS. No questions.

Mr. JONES. Mr. Indritz, do you have any questions?

Mr. INDRITZ. Have you been able to examine the membranes used by the Dutch?

Dr. GREGOR. Yes; I have samples of them.

Mr. INDRITZ. How do they compare with American membranes?

Dr. GREGOR. I say I have examined them. I have done just about the kind of examination you have done. But for me to go into it—I just cannot tell a student to go into the laboratory and look at somebody else's membranes. That is not a research activity, and ordinarily I have not done it. I would just guess they are probably moving in the direction of the way membranes are made in this country. They started out making the molded-type membranes. Now they are going over to membranes like this, which are a homogeneous type.

Mr. JONES. Thank you very much, Doctor. It was a pleasure to have you.

The next witness is Mr. Donald W. Hood, associate professor, department of oceanography and meteorology, Agricultural and Mechanical College of Texas.

## STATEMENT OF DR. DONALD W. HOOD, ASSOCIATE PROFESSOR, DEPARTMENT OF OCEANOGRAPHY AND METEOROLOGY, AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

Mr. JONES. We are glad to have you, sir. Do you have a prepared statement?

Dr. HOOD. Yes, sir.

Mr. JONES. Would you like to summarize that statement, Doctor?

Dr. HOOD. Yes, sir.

(The prepared statement of Dr. Hood is as follows:)

STATEMENT OF DR. DONALD W. HOOD, ASSOCIATE PROFESSOR, DEPARTMENT OF OCEANOGRAPHY AND METEOROLOGY, AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

### GENERAL REMARKS

The opportunity to appear before this committee to discuss with you the saline-water-conversion problem and program is very gratifying to me. This is particularly true since it has been my pleasure to conduct research on desalination of saline water by the liquid-liquid-extraction process since the inception of the saline-water program in 1952. All evidence since that time emphasizes the importance of research in this field and the wisdom of Congress in making provision for encouraging such research in various institutions throughout the United States and in foreign lands. This statement will be concerned primarily with difficulties in the saline-water problem, approaches to the problem, and comments on the program of the Saline Water Office of the Department of the Interior.

### DIFFICULTIES IN THE SALINE-WATER PROBLEMS

*Basic difficulties.*—The potential energy lost when fresh water from the river runs into the sea is equivalent to that of water dropping from a 1,000-foot precipice into the valley below. It is fundamentally impossible to extract fresh water from the sea without adding back this amount of energy to the system. From a practical point of view, it is not possible to approach the thermodynamic limits, for to do so requires an infinitely large capital investment. A more realistic figure

which conceivably could be approached would seem to be the potential energy released by a waterfall of 5,000 to 10,000 feet in height as the amount of energy required to convert sea water to fresh water. This amounts to between 14 and 18 kilowatts of energy for each 1,000 gallons of water. These values are given only for energy, and nothing is allowed for machinery, controls, management, removal of wastes, etc. It may, therefore, be readily seen that fresh water from the sea will require certain minimum amounts of energy, and, no matter how much research is done, these basic requirements can only be approached and never improved upon.

There are many processes now in existence which can produce water for limited use. The major difficulty becomes one of large-scale production of water that can be used for municipal, industrial, and agricultural requirements. In essence, the battle for water must be fought on the economic front. The present market for water at 10 to 30 cents per 1,000 gallons is great, but the supply of such water from conversion processes is far away, if ever in sight, except when very favorable circumstances exist.

*Economic difficulties.*—Water is said to be the cheapest commodity which we now enjoy. The cost of pure, treated water in a third-floor apartment, delivered under pressure and at the site needed, is approximately 5 cents a ton. Were we to deliver air under the same conditions, the cost would be greater; even low-cost sand or gravel would cost approximately a dollar and a quarter a ton. Even under extreme conditions, the cost of water is rarely over 15 cents a ton. Industrial concerns, in general, do not consider it feasible to process a material unless the selling price is something upward of 1 cent a pound; it, therefore, is evident that to produce water by any industrial process one is confronted with cost figures that are not realistic on any production basis now known. Based on the past experience and the basic requirements for desalination of water, it does not seem realistic that large-scale production of potable water can be derived from the sea for much less than 50 cents per 1,000 gallons unless a major breakthrough in such items as power, heat exchange, or better than usual operating expenses are met. This corresponds to approximately $160 per acre-foot.

It is quite likely that brackish water can be converted for a much lower figure than above, and it is conceivable that large quantities of fresh water could be produced for irrigation from this source if the value of the water to the type of crop produced is considered rather than the current costs of available water. In this regard, public education is needed in order to establish the true value of water.

*General engineering problems.*—A number of basic problems which confront the whole saline-water program have been pointed out a number of times, but are worthy of repetition here.

(*a*) Energy: The most basic problem of any desalination method is that of providing a low-cost source of energy. In general, any decrease in cost of energy would result in a corresponding decreased cost of desalination by any of the processes now under study. All the processes do not require the same grade of energy. In some cases, electrical power (the most costly) is required. In others, temperatures as low as 75°–80° are appropriate. In the latter case, it is quite likely that a large supply of these types of energy may be obtained in the form of waste heat from diesel enginess, turbines, or waste steam in industrial plants. The cheapest source of energy, of course, is that of sunlight. However, to use this energy requires considerable investment in capital equipment, resulting in a net cost of the product water as high or higher than those processes which use more expensive forms of energy.

Another system by which the cost of energy can be reduced is that of reuse through a considerable number of cycles. This can be accomplished by heat exchange between the successive cycles.

(*b*) Heat exchange: Some of the projects under study in the saline-water program are primarily concerned with improving heat-exchange systems in order to utilize more of the input energy and at a greater rate before releasing it to the environment. Advances in heat-exchange technology will be very valuable to many of the processes under study.

(*c*) Scaling: Severe scaling of heat-exchange surfaces is one of the basic problems facing desalination processes. A number of laboratories are working on techniques for eliminating scaling of metal surfaces. This would greatly aid in allowing more efficient heat exchange and, therefore, lower the heat-exchanger requirements.

(*d*) Corrosion: Cost of corrosion in marine installations constitutes a serious problem. The Dow Chemical plant at Freeport, Tex., spends several million dollars a year for paint merely to maintain the plant and protect it from corrosion. The equipment itself is subject to extreme corrosion when contacted at high temperatures with saline waters. This problem in general is a difficult one to handle for all desalination processes. Some processes have considerable advantage in this regard since they either require low temperatures or because natural inhibitors to corrosion are part of the operating portion of the process.

Other general engineering problems exist but the three above-mentioned seem to be the most important, and solution of any of these would greatly aid in reducing the cost of potable from saline waters.

*Evaluation difficulties.*—In a broad research program such as undertaken by the Saline Water Office it becomes difficult to evaluate the various processes under study and compare one with the other with respect to feasibility for the production of low-cost water. It is relatively easy to obtain cost data on processes which have been in operation for a number of years such as that of distillation, freezing, and even ionic membranes, since certain past experience reflects on the operating costs and improvements in the processes are easily studied and evaluated. This is not true of newer processes which are investigating phenomenon that have never been put on an operational basis. Thus, all cost estimates must then be related to similar but very different operating procedures. To provide certain basic data for calculation of costs the Office of Saline Water in 1955 published a method for use in cost estimates to be used on all the saline-water projects. Even following this a number of discrepancies have arisen. It is probably not desirable to judge the merits of a process based on cost evaluation since the degree of refinement between processes covers such an extreme range. A truly sound method for evaluating the processes does not exist, but it does seem that every consideration should be given the possibility of breakthrough, in terms of economics, rather than by the evaluation of actual data currently existent for the particular process.

## APPROACHES TO THE PROBLEM

There are six phenomena which form the basis for the various processes now under investigation which are applicable to desalination. These are thermodistillation, solar distillation, electric membrane separation, osmotic processes, solvent extraction, and separation by freezing. In addition to these, some miscellaneous methods of conceivable value have arisen.

*Thermodistillation.*—Of these phenomena, thermodistillation seems to have had more investigations than the others, since it has been a process used both in industry and aboard ships for many years. Most of the research on this process at the present time is done in an effort to refine engineering techniques. It is well advanced over other processes technologically, but has the inherent disadvantage of high temperature requirements; high requirements for heat exchange, and operates under conditions of high corrosion.

*Solar distillation.*—Solar distillation has had considerable investigation; it has the advantage of an infinite amount of low-quality energy which is particularly appealing. Investigations, to this point, have indicated that the capital costs for installation necessary to provide an absorbing surface for sun's energy makes this process more costly than is desired.

*Electrical membranes.*—Electrical membrane separation has probably received more attention during the time of the present saline-water program than any other process and considerable advances have resulted. The process has particular advantage in brackish waters, but would apparently have little value for highly saline waters or sea water. The basic problem here seems to be stability of the membranes to long usage. Research on synthesis and production of low-cost membranes is underway.

*Osmotic processes.*—Osmotic processes are still in the stage of fundamental development and little cost information is available. However, fundamentally the ultrafiltration technique would seem to be one of the most direct processes now under investigation and offers a potential breakthrough providing suitable membranes can be obtained.

*Solvent extraction.*—Solvent extraction process which is now under investigation in our laboratory at Texas A. & M. was conceived about the time of initiation of the saline-water program. Research has been conducted since that time under contract with the Saline Water Office. This process has many ad-

vantages over others and some disadvantages. The chief advantage rests in the fact that it requires only low-quality heat and that the scaling and corrosion problems are minimized by the nature of the material involved. This process, basically, has been said by some to be potentially least expensive of all the methods under investigation. The chief problems are that of obtaining suitable solvents and in recovering these solvents from the water product. Recently, solvents have been synthesized which seem to offer a very strong case for this method. It is believed that continued research will bring the water cost for desalination by liquid-liquid extraction into competition with any of the processes now under investigation.

*Freezing.*—Separation by freezing is potentially very good, providing the ice can be freed of contaminating brine. Of particular interest in this category is that of the direct freezing method in which butane gas, an immiscible liquid, is used in contact with the water to provide the freezing medium. This technique minimizes the heat transfer requirements. Scaling and corrosion are minimal under the conditions used. Continued investigation of this technique should provide water at an attractive price.

All of the above processes are worthy of continued investigation and each seems to have certain advantages over each of the others. Which one is the most promising at the present time is more of a guess than an estimate, and it is quite necessary that investigation be continued in all phases that have not been shown to be unreasonably costly because of fundamental difficulties.

It is likely that potential processes exist that would be well worth studying in order to improve on certain points of the above processes or create a completely new and/or novel technique. Scientific groups should be encouraged to consider the desalination problem as a field of endeavor. All worthy ideas should continue to be supported and at a rate which would encourage the most capable scientists to participate.

### PROGRAM OF THE OFFICE OF SALINE WATER

It is my opinion that the Office of Saline Water has conducted the research program assigned to them in a manner which is commendable. This is especially true when one considers the funds available and restrictions of the program set down under the Public Law No. 448 of the 82d Congress. Mr. Stroebel and Mr. Gilliam of this program have been particularly helpful in coordinating the program and have been efficient and helpful in administering the contract on which I have participated. It does appear that the administrative staff of the Office should have an increase in personnel in order to perform all the duties demanded of it in an efficient manner.

Under guidance of this Office, considerable progress has been made in the desalination of saline water. I have heard and read comments to the effect that nothing seems to have been accomplished during the 6-year period of this Office's existence. As a scientist, I feel that those remarks are completely unfounded and that research effort has brought together an outstanding group of people who are studying the problem of economic production of potable water from saline water for the good of the Nation. The economic production of saline waters is a very big scientific problem. It requires all the knowhow and cleverness involved in discovery of new techniques and new ideas coupled with tying this information to economic engineering practices. It is not unreasonable to expect this program to require a period of considerable time to evolve desired goals. The problem of desalination is no less difficult than the problem of power from atomic energy. If one would compare the amounts of money expended in each of these areas it could easily be seen that the performance of the desalination program has been outstanding. Since water is generally recognized as being a very inexpensive commodity, I fear that this philosophy has been carried over into underwriting the research program on desalination and production of water. To accomplish the task at hand will require a large amount of money, concentrated effort and continuity of the program.

*Weaknesses of the program.*—The program as set up is very difficult for scientific groups to administer for various reasons. The first and foremost of these is that the sponsorship is such that it is impossible to establish continuity of program. There is far too much emphasis on cost estimation rather than obtaining fundamental data which eventually will allow successful conclusion of a research effort. Because of the lack of guarantee of continuity of the research effort, it is almost impossible to get the quality of research people needed to engage in the program. Even graduate students normally cannot meet their

academic requirements in less than 18 months or 2 years for a master's degree, and 3 to 4 years for Ph. D. These people find a period of a 1-year contract much too uncertain for them to gamble with this type of support in planning their research problem. The National Science Foundation and the American Institute of Health recognize this problem in their research programs and, therefore, have provided for 2- to 5-year programs in which the grantee has money allotted for several years ahead on which to plan his work and obtain high quality personnel. The second weak point is the requirement placed on all the projects that some type of cost estimate must be arrived at very early in the research program. In many cases the data are insufficient to make accurate cost estimates possible. Considerable amount of time and effort is spent on this phase of the program that could be better spent in studying the fundamentals. Once these had been worked out it would then be possible to arrive at a reliable estimate of cost for the process. Many groups are interested in the fundamentals of a process and are, therefore, discouraged in this research effort because of these requirements. The third weakness is that too little support is provided in the program in order to carry out the work that is deemed most desirable and at a rate which is most efficient. In a research program it is usually possible to do as much as twice the amount of work with 25 percent more money merely because certain continuing costs, such as report writing, laboratory technicians, etc., use up a fairly standard amount of the project funds. Additional amounts of money will frequently allow other important problems to be attacked.

### HOW TO STRENGTHEN THE PROGRAM

In general the greatest single thing that the Government could do in accelerating this program is to establish a continuing type of support to research groups in this country who are undertaking study of this problem. Support should not be on a year to year basis. There should be established at different places a unit of research people who are interested and capable of working on the problem so that they may continue their effort from year to year without fear of having to look elsewhere for gainful employment. In our own particular case we feel that probably 30 percent more progress could have been made during the past 5 years had it been determined when the research was initiated that this program would be continued for a period of years or until it was found impractical to continue. This would have allowed personnel acquisition and continued interest on the part of the people concerned. It would be difficult for me to overemphasize the importance at this point. Secondly, the Government would probably realize more for its investment if research funds expended were placed at truly research organizations such as academic institutions and some of the better research foundations. If placed in academic institutions where graduate students would find interesting problems for graduate research, the saline water program would not only have received data of value but would have trained men in an area in which they would continue to function through their productive years. The saline water program cannot continue to accomplish results unless some system for training personnel is established and maintained. It would seem advisable that a good portion of the saline water funds be placed on the university campuses with the requirement that a certain part of the personnel be graduate students.

Thirdly, it would help the program if the Saline Water Office should be removed from political pressure so far as is possible. This would allow the group to function in a way to be most helpful to the grantees and would allow for the Saline Water Office personnel to work closer to the problem, and in particular spend more time on those processes which may allow for a breakthrough of the economic barrier. The program would also be strengthened, I believe, if divided into two sections. The first of these would be classified as fundamental research. In this category would fall such processes as liquid-liquid extraction, ultrafiltration, direct contact freezing, synthesis of electrical membranes, and other basic problems which are important to one or all of the processes. Into the second group would fall such studies as distillation, improving of standard techniques of freezing, pilot plant work on permionic membranes, etc. In the first group the project should not be required to prepare cost estimates. The work done here should be judged on the merit of the research accomplished and the potential value of the results obtained. The second class would perhaps enter into pilot plant stage at an early date and, therefore, have the necessary information to arrive at satisfactory cost estimates.

The Government should be interested in obtaining all the information it can concerning the desalination of sea water, either fundamental or applied. No process should be neglected that has potential value for economic desalination.

SUMMARY

The general overall saline water program for the past 6 years has enjoyed a high degree of performance and success. It is felt that a number of points could be strengthened in this program, particularly that of maintaining continuity of sponsorship, emphasizing research at academic institutions, and providing for a greater training program in the area of desalination. It is strongly felt that all phases of the desalination program should be accelerated with particular emphasis on fundamental research so that the processes which are new and are, therefore, in need of considerable laboratory effort are not relegated a minority role with regard to those processes which are older and, therefore, are automatically operating at the stage of greater refinement of the art. Fresh water from brackish waters may be needed now and certainly in most cases it is rather definite that it will be needed in not more than 15 to 20 years hence in many situations in this country and in the world. It is felt that a sound research program is what is needed at this time, and that a crash program would be highly undesirable because at the present time no one process enjoys sufficient leadership in the field to justify investment of large amounts of money for what would probably end up being a white elephant after a very brief period when other processes are developed and become more efficient.

There is a ready market at the present time for water of the 10 to 30 cents per 1,000 gallon class; there are not many groups in this country that would be willing to pay 75 cents per thousand gallons which is about the best that can be expected from sea water feed by any process now known.

Dr. HOOD. Many of the points in the statement have been covered or reviewed today more adequately or more precisely than I intended to do, so I will quickly summarize some major points.

First, the difficulty encountered in the saline water problem might be worthy of reiteration at this point. It is fundamentally impossible to get water for less than 2.8 kilowatts per thousand gallons. The potential energy that has to be returned to the system here is equivalent to that which is given up by a thousand-foot drop from the top of a cliff to the valley below. If this is not a practical figure, someone this morning said it might be when you get 20 percent efficiency. This would mean that we are having to supply energy to water which normally is gotten free to lift it to a head of some 5,000 to 10,000 feet. That is a fundamental requirement in the desalination of sea water. In addition to this come all the machinery costs, distribution costs, management costs, and what have you.

It was clearly stated, and I can state it again, that the battle for economic water must be fought for desalination on an economic front. So this leads us to consider the economic difficulties encountered.

In the first place, water is the cheapest commodity we have anything to do with. For 5 cents a ton you get this stuff delivered to a third floor apartment under pressure at a faucet, the way you like it, which as someone expressed this morning can be compared to sand or gravel, which comes to you at a dollar and a quarter or dollar and a half a ton, and then they dump it in your front yard or at your garage and you still have to move it.

The other consideration is that industry in general does not consider a process worthy of consideration unless something near 1 cent a pound or about $80 per thousand gallons can be realized from it. Even boiler water treatment costs considerably more than the figures

we are shooting at for desalination of water if we pick the lower values estimated.

Considering all this, I think it is probably not feasible ever to get potable water from the sea for less than 50 cents a thousand gallons, which is about $160 per acre-foot. On the other hand, potable water from this source is certainly worth more than 50 cents a thousand gallons under many conditions, and in the years projected ahead it probably may be worth that in many more than we even suspect.

The engineering problems encountered have been reviewed. I would like to point out a few things. The cost required to pump this water a thousand feet into the air that we spoke of earlier is approximately 6 cents a thousand gallons if you use steam. If you use electricity it is perhaps 8 cents a thousand gallons. This brings up the importance of energy and the importance of differences between processes. All processes do not require the same type. Sunlight, for instance, is free energy, but because of the difficulty in harnessing it the cost of potable water by this process is perhaps not as low as some of the others. So any research in the area of energy would be valuable in the area of desalination.

Another major problem that has been mentioned is heat exchange. All or almost all the processes require efficient heat exchange, because this heat has to be reused a number of times before you turn it loose in the environment, and research in this area is much needed.

Another problem is scaling. I think this has been brought out sufficiently. And of course another is corrosion.

These four basic engineering problems face almost every process we attempt to deal with in brackish water, and particularly in sea water.

The next point I would like to mention is the difficulty in evaluating progress on the various processes. Obviously, if you have to evaluate something the more background information you can have, the more history you have at your disposal, the easier it is going to be to arrive at an accurate figure. I refer to such processes as distillation, perhaps freezing, and some of the others which can be more easily evaluated than some of the newer ones such as solvent extraction, which I represent. I think it is undesirable to judge a process entirely on cost data, but rather it should be judged on the possibility of breakthrough to a new and cheaper water. You cannot see the breakthrough until you get to it, and if you are too quick to judge you may find that you missed the opportunity to get cheap water.

There are a number of general problems in the approach to this problem. Thermal distillation has the disadvantage of high heat requirement, high heat exchange ratios, corrosion and scaling. Solar distillation has the disadvantage that it has to harness a very low energy source, and this is expensive. Electric membranes we have just heard discussed. These have some disadvantages, in that the membranes do not have long enough life to perhaps carry on indefinitely and are not applicable to sea water.

Osmotic processes are relatively undeveloped, but in this area lie some processes that are probably the most direct and simplest of any of the processes, one of which is ultrafiltration, in which you force water through a membrane which will not allow the salt to pass and thereby obtain fresh water. Another process under investigation is

solvent extraction, one that we have been looking at for about 6 years, a relatively new idea in which we are still working on the fundamentals, and if you would like later I will discuss the details of it. Then comes freezing.

Now, all of these processes, and there are some miscellaneous ones, are worthy of study. I think scientific groups should be encouraged to study this field of application as a permanent endeavor, rather than one which is sporadic and happens to be created because of possible funds. There should be a certain nucleus of scientific people in this country who are interested in desalination problems in general, educated in all the aspects of desalination and perhaps working in one area as a specialist. All the ideas to find new approaches to the problem should be encouraged, and should be encouraged to the extent that we have the most competent people we can get willing to participate in this program.

Now I come to the point of discussing the program of the Office of Saline Water, which has been underway since 1952. I think the program has been conducted in a commendable manner. We have had a contract with them ever since the inception, I believe. I personally do not feel that the problem of desalinated sea water is necessarily any more difficult than perhaps harnessing the atom for atomic energy.

Now, I think economic production of desalinated water is a big scientific problem and not one which is to be encountered when the whim strikes us and abandoned a few days later. This indicates a training program. It is going to require all the cleverness involved in basic research and your techniques of putting this to practical application in order to get water down to the cost we would like to see and which we will need to have as our economy progresses.

I would like to say a few words now about how to strengthen this program. The greatest single thing I think the Government can do to accelerate this program is to establish a type of continuing support, and establish this in research groups who are recognized academic, or other well known and well fortified research institutions.

Mr. JONES. You mean academic institutions?

Dr. HOOD. I think there should be more emphasis placed here. I am building to the point that for the program to succeed I think we need trained people in the field, and about the only place you can do this is to have a strong nucleus of people coming out of colleges who know how to get at this problem and know what the problem really entails.

Mr. JONES. That same point was made by Dr. Waterman, of the National Science Foundation, in pointing out the need for that kind of assignment for most of the basic research programs or projects.

Dr. HOOD. I think to accomplish this the program should not be on a year-to-year basis but should be done similar to the National Science Foundation or National Institutes of Health, which recognize the difficulty of getting research groups interested in problems in a continuing manner. I know in my own case it is very difficult to get a graduate student on this program, the reason being that he realizes that perhaps at the end of a year there will be no more support, or at least the possibility always exists, and he hates to indulge himself in this activity and find out he cannot carry on because of the budget.

If it were a situation where you had it on a 2- or 3-year basis to pursue a problem until you come to a successful conclusion and then evaluate it as to its worth to desalination based on cost, you could get people who were enthusiastic workers in the acedemic area, who would not only produce the projects and become trained in the field, but if they had not learned anything adaptable to saline water they would have produced an enormous amount of fundamental data which could be used in other things. I think in our own case probably 30 percent more progress would have been made had we had continuity of support from the beginning until now. The present law I do not believe provides for this type of sponsorship. I think this about concludes my general statement, and I might summarize.

I believe that all phases of desalination programs should be accelerated, with particular emphasis on fundamental research, so that the processes which are new and therefore in need of considerable laboratory effort are not neglected and given a minority role in relation to those processes which are older and have more known regarding them.

I think that there is considerable market at the present time for a good method for desalinating brackish water. I think perhaps the permeable selective membrane method is appropriate, but I think also there are others which have a good chance of competition here. I speak here of the solvent extraction possibilities.

I think that this is no time for a crash program but a time for a steady forward effort, to learn as much about these basic engineering problems as we can and apply them as we can to the needs of the country in particular locations as these needs arise. I believe no one process will ever solve all the problems but it will be a combination suitable to a particular situation.

I think there probably is a ready market at the present time for water at 10 to 30 cents per thousand gallons, but I do not see too many people who are willing to pay the 75 cents which is about the best that can be currently done. So we should push forward in an attempt to improve methods not yet too well defined but that have potential of becoming very economical.

Mr. JONES. Thank you very much, Doctor. Mrs. Granahan?

Mrs. GRANAHAN. No questions.

Mr. JONES. Mr. Moss?

Mr. MOSS. No questions.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. In connection with the support that is given by the Office of Saline Water in its contract relationships with academic institutions, do you think that the contracts should be on a long-term basis, or do you thing that one-year contracts would be adequate?

Dr. HOOD. I think the funds should be allotted initially, and then satisfactory progress would allow continuity of the program. The current method is that the project ends at a specified period of time, at which time renewal is necessary. It takes quite a bit of review and there is uncertainty. It is difficult to keep people who are working on these problems interested when there is the possibility that they will be out of a job or have to take another problem in the near future. So I think the method would be to allot 3 years' funds in this project, and if things go on as expected and progress is normal

they would just be automatically picked up at the end of each contract year or a 3-year contract.

Mr. INDRITZ. But you do think there would be great advantage gained in the research program when it is tied in with the university and other academic research and scholastic programs?

Dr. HOOD. I definitely do. There is an excellent opportunity here to provide graduate students sponsorship and encouragement to do fundamental research.

Mr. JONES. Let me interrupt you. I see your first contract was for 20 months and the last one you executed was for 12 months. The point you are making is you would like to have longer contract periods?

Dr. HOOD. Yes. I think the 20-month one actually was for perhaps a year, and then rather than making a new contract it was extended, but we did not know the extension would occur.

Mr. INDRITZ. Are you aware that a number of universities have cooperative agreements with agencies of Government, whereby projects that the Government agency may be interested in are worked on by the professors and the graduate students, and that the university assumes part of the cost by helping to provide the laboratory? Would you suggest that the Office of Saline Water engage in more of that effort?

Dr. HOOD. I think you are speaking of AEC particularly here.

Mr. INDRITZ. Your Department has some of that. Also the Bureau of Mines has some.

Dr. HOOD. This program works out very well. In fact, we have some of each of the ones I mentioned.

Mr. INDRITZ. Those are usually low-cost contracts in terms of expenditure by the Government?

Dr. HOOD. Well, AEC I believe is fairly liberal, as are the National Institutes of Health.

Mr. INDRITZ. I mean low cost in comparison with what they might get.

Dr. HOOD. Yes; the 30 percent expenditure of the university is not a fixed figure, but if the university is willing to put 30 percent in they would carry the rest, two-thirds of the cost.

Mr. INDRITZ. You believe there are many universities that would be willing to engage in that type of cooperative work?

Dr. HOOD. Yes; I am sure they would. The reason they can do this is that they have programs, facilities, and people. To provide this 30 percent does not necessarily cost them any dollars. It allows this contract to use their present facilities to better advantage. I think in various research efforts the administration does not go up very greatly when you add a new project. In this way the use of special equipment which is already there is available to you for a certain amount of time, and this is essentially free to the university and to the contractor.

Mr. INDRITZ. Are you saying that with the addition of a fairly small amount of research funds the value of the research funds may be doubled or tripled because the overhead remains pretty much the same?

Dr. HOOD. That is right; that is the point.

Mr. INDRITZ. Are you familiar with any difficulties that have been found in membranes in New Mexico due to sulfate ions?

Dr. HOOD. I am not too familiar with that. I do know a person who is working I think in a Government installation using a membrane type for desalination of brackish water, and sulfate ions have given considerable trouble. In fact, he was ready to do most anything except run the item. In some work we have done in the laboratory, not on the desalination problem at all but in an attempt to isolate the organic materials from sea water, we made use of some of the processes that desalinate water, to take the ions out and leave the organic material behind, and we found invariably that the material which we concentrated finally contained a large concentration of sulfate ions. So I rather expect it might be a bad actor in general. Any further than that, I am sure that people present here can say more about it than I can.

Mr. INDRITZ. Do you have any other suggestions that you might want to offer to the committee as to how the Federal Government might expedite its program and increase the effort in research and development on saline water?

Dr. HOOD. I do not know how to do this, but I would like to see a little more State activity in this area. In the State of Texas, I am aware of a considerable amount of interest at the present time in water conservation. I am not aware of a single State effort in desalination or water conversion.

Mr. INDRITZ. There are considerable saline waters that cause trouble in Texas; is that not so?

Dr. HOOD. Yes, and during the drought years there was even consideration of putting in any type of treatment plant just in an attempt to save what citrus was still there. Since the rains have come and the pressure is off a little, I am sure they would not be interested in this, but the amount of brackish water in Texas is probably adequate to provide her needs for a considerable number of years if properly treated.

Mr. INDRITZ. So that if the desalination program of the Office of Saline Water achieved success with respect to the treatment of brackish water it could prove a very great boon to the State of Texas?

Dr. HOOD. It certainly could. I think they would be one of your best customers.

Mr. JONES. Thank you very much, Dr. Hood. It has been a pleasure to have you, and I assure you your testimony is quite valuable.

Dr. HOOD. I enjoyed being here.

Mr. JONES. Last week Mr. Harvey O. Banks, director of water resources for the State of California, called me from Sacramento and told me that he would not be able to come due to the fact that the Legislature of the State of California was in session. He said he would send some representative. I understand that Mr. Berry and Mr. Koch are present. Please come around, gentlemen. Will you identify yourselves for the record?

## STATEMENT OF WILLIAM BERRY, CHIEF ENGINEER, DIVISION OF RESOURCES PLANNING, CALIFORNIA DEPARTMENT OF WATER RESOURCES; ACCOMPANIED BY ALBERT KOCH, SPECIAL CONSULTANT ON SALINE WATER CONVERSION

Mr. BERRY. My name is William Berry. I am chief engineer of the division of resources planning, California Department of Water Resources. I am accompanied by Mr. Albert Koch, special consultant on saline water conversion. I am representing Mr. Harvey O. Banks, who is the director of that department.

I do not have a prepared statement. I do have a statement that Mr. Banks made before the Subcommittee on Irrigation and Reclamation of the Senate Committee on Interior and Insular Affairs on March 21, and would like to speak from that if I may.

Mr. JONES. Go right ahead.

Mr. BERRY. We will be most happy to prepare a statement and present it to you at a later date, if you care to have it.

Mr. JONES. We would be glad to have it, Mr. Berry, and it will be made a part of the record.

Mr. BERRY. California, of course, is deeply interested in the possibilities of demineralization of saline water as a source of fresh-water supply, and we do offer our full support and cooperation to the Congress and to the Federal agencies concerned in carrying these studies through to a conclusion. We are also interested in the development of nuclear energy, since we feel that these two matters; that is, demineralization of sea water and nuclear energy, are definitely related. Without large amounts of cheap energy becoming available in the future from nuclear sources, it does not appear that any demineralization process now envisioned offers promise of producing fresh water from sea water in large quantities and at costs economically competitive with other sources in most areas.

I want to touch briefly on our water problems in California and the studies now being undertaken on demineralization of saline water and of nuclear energy, and the possible applications thereof to the solution of these problems.

To meet the present and future water needs throughout California, the State has evolved a master program of multi-purpose water development known as the California water plan. Such a plan is vitally needed to assure that optimum benefits shall accrue in the control, conservation, protection, distribution, and utilization of the waters of California for all regions of the State and for all uses of water. To fully accomplish the California water plan will require much time, perhaps a century or more; the expenditure of more than $12 billion; and the combined efforts of Federal, State, and local governments and private enterprise.

I may interject here that this relates somewhat, I believe, to the comments of one of the earlier witnesses, that is, to the need for overall planning for the solution of these water problems.

Our present studies indicate that the ultimate water needs of California will approximate 2½ times the amount now required. I may again interject we do have very urgent immediate water problems in California.

Mr. JONES. Mr. Berry, you are going to have two basin programs. There is going to be a deficit in authorization with this recent veto of the flood control and river and harbor bill.

Mr. BERRY. Yes.

Mr. JONES. How is that going to affect prosecution of that work in California?

Mr. BERRY. Well, I do not say—some particular projects may be delayed. Specifically we had hoped there would be authorization, Federal authorization, in connection with our Oroville Dam of the Feather River project.

Mr. JONES. I see. I think $40 million was the authorization for that.

Mr. BERRY. I believe the figure was $50 million.

Mr. MOSS. I believe the figure was to be considered later.

Mr. JONES. It was to be around $40 million.

Mr. MOSS. Highest was around $100 million.

Mr. BERRY. The Corps of Engineers would come out with a recommendation as to the exact figure.

Mr. JONES. Yes, sir.

Mr. BERRY. We do have immediate flood-control problems in California. We have, however, many authorized projects in California that are not being constructed.

Mr. JONES. Well, I understood that was going to be the sequence of development and it was of primary importance that you would get the authorization so you would not abate the work that was being done conjunctively in the State.

Mr. BERRY. I think that is right. Of course, the Feather River project is not the only project in California. We have other reservoir flood control projects in the Sacramento and San Joaquin Valleys, the New Melones, New Hogan, Black Butte Dams and others that are current. We have had some recent demonstrations of the need for those projects.

Mr. JONES. Yes. Well, I understood that the plan had been concurred in by all the local agencies in the State of California making recommendation to the Congress to include it in an authorization bill, and that that was what the local authorities and the Corps of Engineers had agreed upon as the order of prosecution of that work.

Mr. BERRY. I think that is right. Now, whether all of the very large interregional transfers of water now envisioned as necessary in the future to supply California's increasing needs for water will finally be constructed or whether the demineralization of brackish and seawater will provide some of the future requirements is as yet a matter of conjecture. If competitive demineralization processes are developed, the locale of application will largely be dictated by economics. Obviously large savings may be possible.

The California State Legislature fully realizes the probable implications to the State's interests of developments in the field of water demineralization and in the application of nuclear energy to solution of water problems, as does the department of water resources. During the past year, a legislative interim committee has been actively studying these matters. Assemblyman Jack Beaver, chairman of that committee, has been very active in the study of all of these matters which we are discussing here today.

It is anticipated that the legislature will appropriate approximately $104,000 to the department of water resources for the fiscal year 1958–59 for investigations in the fields of demineralization and nuclear energy, with the directive that these studies be expedited as much as possible. Concurrently, the legislature has similarly requested the University of California to speed up and expand its basic research programs.

And I may interject here that the budget of the university for the next fiscal year is nearly $500,000 for this same purpose.

Mr. JONES. Is that the University of California at Los Angeles?

Mr. BERRY. That is right, in Los Angeles and in Berkeley.

Mr. JONES. Yes. Now, I believe the University of California at Los Angeles already has a contract with the Office of Saline Waters.

Mr. BERRY. I believe that is correct.

Mr. JONES. Now is that the accelerated program you are talking about here?

Mr. BERRY. Yes; I mentioned the figure $500,000. That is 2 or 3 times what they have had this current year.

Now, to accomplish this expanded program, the California Department of Water Resources is now organizing a specialized, highly technical engineering section to investigate not only all phases of the sea- and brackish-water conversion problem, but also to study the possible uses of nuclear energy as sources of heat or electrical energy for demineralization processes and as sources of electrical or mechanical energy for pumping. Several specialists have already been recruited, and Mr. Koch is the head of that activity.

The latter studies will include full consideration of the possibilities of the generation of hydroelectric energy for peaking purposes through the use of pumped-storage using offpeak energy from nuclear reactors and/or other sources for pumping.

Should definite profitable avenues for further investigation and development be revealed, the Department will, subject to the availability of funds, take full advantage of possible cooperative arrangements with Federal and other public agencies and of the employment of private organizations to continue detailed investigational and developmental work. A considerable number of private companies have been contacted and are ready to assist the department when it appears advantageous to actively pursue definite developmental phases.

With regard to the need of large-scale water demineralization plants and the applications of nuclear energy in California's water development program, it is believed that at least 5 years are yet available before definite decisions must be made regarding possible major applications. Thus we have ample time to conduct the basic research and pilot-plant studies which are still necessary to obtain conclusive information as to processes, materials, design data, and costs.

The most immediate need for large amounts of supplemental fresh water in California is for irrigation in the San Joaquin Valley. There is no prospect whatsoever that this need could be met by demineralization of sea water at costs even approaching those involved in conserving and importing fresh water from streams of the Sacramento Valley, such as the Feather River. However, the demineralization of brackish drainage water may offer some promise in the future.

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The immediate efforts of the department of water resources in the field of water demineralization are directed toward (1) the collection of all available research data, and design, operation and maintenance data for existing and planned saline-water conversion units in the United States and abroad; (2) putting these data on common bases to enable comparative analyses; and (3) evaluation to determine the most promising processes, possibilities of new processes and cost and design data.

We are working closely with the Office of Saline Water in the scientific and technical phases of the water demineralization program. Close cooperation is being maintained with the research work of the University of California at Berkeley and at Los Angeles in the fields of saline-water conversion processes and low-temperature nuclear reactor development.

It is also contemplated that arrangements may be made for supplementary studies by such organizations as Scripps Institute of Oceanography, Stanford University, Stanford Research Institute, California Institute of Technology, Massachusetts Institute of Technology, and the University of Wisconsin.

Prepilot plant investigations will soon be initiated for several locations in California, including use of processes suitable for the demineralization of brackish drainage water in the central San Joaquin Valley, reclamation of sewage, and the possibilities of sea-water conversion units in the vicinity of Monterey, the San Luis Obispo-Santa Barbara region, Los Angeles, Avalon, and at San Diego. These sea-water conversion unit studies will consider the use of waste industrial heat sources and the use of the thermal potential of sea water in coastal submarine basins and canyons, perhaps supplemented by solar heating of surface waters and/or by secondary electrical or heat energy.

Our studies to date indicate that no demineralization process for the conversion of sea water in its present stage of development appears to be competitive in most areas of California with water from natural sources. It is our opinion that to be useful to consumers of domestic, municipal, and industrial water in California, the total cost must show promise of ultimately approaching $80 per acre-foot. This figure is very nearly that of the cost of fuel or of energy alone in the majority of the more economical conversion processes developed to this date. Further research and development will no doubt lower the costs substantially below those which now appear possible.

Therefore, it is believed that at this time, we do not have the fundamental knowledge required to select the best process, nor the design data necessary for the construction of a large sea water desalting plant. Rather, there is need for more basic research closely coordinated with careful and detailed engineering analysis so as to obtain reliable operational and cost data for those processes that appear to offer promise of solutions to the problems of demineralization. Such studies should be expedited as much as possible.

As I have stated, large areas of California have water requirements, both present and future, far in excess of their local water resources. These include the San Francisco Bay area, central coastal area, southern California, San Joaquin Valley, the Lahontan region, and the desert areas.

At the present time, our most urgent water problems are those of the interior valleys. Demineralization of sea water may well assist in the future alleviation of the water-shortage problems of the coastal areas. In the interior areas, as previously noted, demineralization of brackish drainage waters appears worthy of future study. Therefore, we believe that further research, experimentation, and finally, operation of large-size pilot or demonstration plants for the desalting of both sea water and brackish water should be conducted as expeditiously as possible. The most feasible process may not be the same in each case.

With respect to the locations of a demonstration plant or plants, it is believed that California, because of the wide variety of our water problems and the urgency thereof, should be selected.

I want to assure you that California will be more than willing to cooperate to the fullest possible extent in the design, construction, and operation of a demonstration plant at the appropriate time, either for demineralization of sea water or brackish water, or both.

In summary, the following points are suggested for your consideration: Since, as yet, no definite water-demineralization process has shown itself to be economically competitive with natural sources of supply, the construction of a demonstration plant should not be undertaken for a year or two until a thorough, detailed appraisal of present processes and existing plants is obtained, and possibly more profitable avenues of research are determined and evaluated.

More factual information should be obtained and pre-pilot-plant engineering studies should be conducted so as to procure sound bases for the selection of possible economically justified methods and of plant locations.

When the investigations result in the selection of a process or processes which appear to offer solutions to the problem of economical water demineralization at specific locations, then demonstration plants should be constructed and operated to obtain full and accurate design and cost data. Such studies should encompass the demineralization of both sea water and brackish water.

We do urge the passage by Congress of legislation to expedite the research program on demineralization of saline water and to provide for construction of demonstration plants. At least 1 year, and in all probability, longer, will be required to conduct the necessary research and studies to properly select the processes and determine the proper locations for demonstration plants. To shortcut these essential first steps might well result in costly failure.

Once the decision has been made to construct a demonstration plant, we strongly recommend that it be located in California. The State of California is willing and anxious to cooperate in every way possible in the solution of this problem.

Mr. JONES. Thank you, Mr. Berry.

Now, do you have a statement, sir, that you would like to make?

Mr. KOCH. No, sir.

Mr. JONES. Mr. Moss, any questions?

Mr. Moss. Not at the moment.

Mr. JONES. Do you plan, while you are here, Mr. Berry, to talk with the officials of the Office of Saline Water, about a cooperative enterprise project?

Mr. BERRY. We have an agreement in process. I do not believe it has been completely negotiated at this moment. We have talked with the Office of Saline Water this morning.

Mr. JONES. You are in negotiation with them now?

Mr. BERRY. Oh, yes; yes. And I think that this agreement, which is about to be completed, will formalize the cooperative effort between the State of California and the Office of Saline Water.[1]

Further than that, we have in prospect a financial contribution by the State to extend some of the studies that the Office of Saline Water is now conducting. We anticipate that, after July 1, when our funds become available, we will contribute financially to the completion of some of the studies that are now underway.

I think this work is being conducted by the Fluor Corp., and we anticipate that the State of California will contribute $40,000 or $50,000 to that effort.

Mr. JONES. With whom?

Mr. BERRY. With the Office of Saline Water for the work being done by——

Mr. JONES. The Fluor Corp.?

Mr. BERRY. By the Fluor Corp.

Mr. JONES Do you have any questions?

Mr. INDRITZ. I have just one question, Mr. Berry.

You spoke in terms of demonstration plants. The Assistant Secretary of the Interior previously advised this committee that the distinction between a demonstration plant and a pilot plant is based on the purpose of the plant; namely, that, if the plant is simply for showing the completed process, it is a demonstration plant. But if it is for the purpose of further research, it is a pilot plant. On the basis of that distinction, your recommendations apply to which type of plant?

Mr. BERRY. I would like to discuss definitions to clarify the intent of this statement. This statement was written specifically for hearings before this other committee.

Mr. JONES. Yes.

Mr. BERRY. And, at that time, they were considering Senate Joint Resolution 135. I think the terminology was "demonstration plant" in that resolution.

Actually, what we are talking about is large-scale pilot plants. Now, to my way of thinking, a demonstration plant implies that you have arrived at something and you are demonstrating that it is feasible and practical. Actually, what we are talking about now is still a research type of facility, I am sure. We are not in a position to demonstrate anything, and will not be in the near future.

Mr. INDRITZ. You were not suggesting, therefore, the construction of large-scale production facilities on the basis simply of existing knowledge without the purpose of acquiring additional or further knowledge?

Mr. BERRY. No; I do think we are going to have to construct fairly large-scale plants to research the engineering-economic factors involved in these plants, and that, essentially, is what I am talking about as demonstration plant. The terminology is, certainly, con-

[1] This agreement appears in the aappendix below as exhibit 9, p. 366.

fused. We have demonstration plants, prototype plants, and pilot plants, and such. But anything that I mention here today is in the nature of research, large-scale research plants.

Mr. INDRITZ. Is your department familiar with smaller type units, such as the Hickman still and the membrane process, which, as an individual unit, can produce only a fairly small quantity of water?

Mr. BERRY. That is right.

Mr. INDRITZ. If there were many of them, they might be able to take care of the needs of the area?

Mr. BERRY. Yes.

Mr. JONES. Any further questions?

Thank you, gentlemen. I appreciate your coming. Give our regards to Mr. Banks, and you tell him that you all gave a good accounting of his office.

Mr. BERRY. We will be very happy to do that. Thank you.

Mr. JONES. Tomorrow we will attempt to conclude the hearings. We have several witnesses to be heard.

The subcommittee will stand adjourned until 10 o'clock tomorrow.

(Whereupon, at 3:33 p. m., the subcommittee adjourned, to reconvene at 10 a. m., Friday, April 18, 1958.)

# SALINE WATER PROGRAM

## (Research and Development)

FRIDAY, APRIL 18, 1958

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON PUBLIC WORKS AND RESOURCES,
OF THE COMMITTEE ON GOVERNMENT OPERATIONS,
*Washington, D. C.*

The subcommittee met, pursuant to adjournment, at 10 a. m., in room 1501, New House Office Building, Hon. Robert E. Jones, chairman of the subcommittee, presiding.

Present: Congressmen Jones, Fascell, Knox, and Brownson.

Also present: Arthur Perlman, staff administrator; Phineas Indritz, subcommittee counsel; Miles Q. Romney, professional staff member; and J. P. Carlson, minority counsel.

Mr. JONES. The subcommittee will come to order.

Mr. Gilbert Levin, sanitary engineer, Resources Research, Inc., Washington, D. C.

Will you come around, please, sir?

All right, Mr. Levin. You may proceed.

### STATEMENT OF GILBERT LEVIN, SANITARY ENGINEER, RESOURCES RESEARCH, INC., WASHINGTON, D. C.

Mr. LEVIN. Mr. Chairman and gentlemen, my name is Gilbert Levin. I am a sanitary engineer with Resources Research, Inc. I am at present consultant to the Joint Committee on Washington Metropolitan Problems, and have written two reports for them, one on water supply in the Washington metropolitan area and the other on sewage disposal and water pollution in the metropolitan area.

I have also worked for the Office of Saline Water and, in October 1957, completed a contract report for them entitled "Survey of Physiological Mechanisms of Sodium and Chloride Ion Transport and Design of Experiment for Application to Demineralizing Saline Waters."

I would like briefly to discuss this proposed method. At the present time, we are about to complete an agreement with the Office of Saline Water to do some original investigation of this proposed method. My original work for the Office of Saline Water which led to this report was primarily a literature survey into the physiological mechanisms whereby all living organisms continually separate salt from water, and either maintain high or low internal concentrations of these salts, including sodium and chloride, with respect to their

environment. This approach had never been tried before, and it more or less is in the line of a basic study.

I found, in reviewing the medical and biochemical literature, ranging all the way from human kidneys, which perform this operation very efficiently, on down to single-celled organisms such as algae, and even to individual cells in organic material, that the process is fairly common, it is universal, and it is believed that the mechanism or mechanisms are fairly common.

About 95 percent of the literature, or the authors of the literature, agree that organisms concentrate ions against the concentration gradients, or against gradients, and maintain them by the expenditure of metabolic energy, that is, by the expenditure of energy they derive from their life processes, and that it is necessary to continue to expend this energy by some mechanism which is still fairly poorly understood, to maintain the difference in concentration, let us say, of sodium within a cell, as compared to the fluid that the cell is constantly bathed in.

The initial report concluded with a proposed experiment which would utilize algae in an attempt to see whether the single-celled organisms could remove salt from sea water or brackish water.

I did some comparison of the energies involved to determine what the relative efficiencies might be between natural processes and the mechanical processes that are being tried now to achieve practical methods. It has been reported that the minimum conceivable energy with which salt can be separated from 1 gallon of sea water is 2.8 watt-hours.

Mr. JONES. Two what?

Mr. LEVIN. 2.8 watt-hours. That is, per gallon of sea water. The literature also states, from the Office of Saline Water, that it looks like the best possible bet for distillation would be in the range of 76.6 watt-hours per gallon of seawater. The electrodialysis process, or the selective-membrane process, because of the cost of the membrane, would not be applicable to sea water, but in brackish waters it will range, in the reference that I have cited, from approximately 1,600 to as high as—I am going to qualify it—from 1,600 to 16,000 watt-hours per gallon for sea water, which, as I say, is too high for a practical application, and is not used for sea water. But this gives a range of comparison.

You have the theoretical minimum of 2.8; and distillation, 76.6; and selective membrane considerably higher.

On the basis of calculations I made from the extensive literature on this process as it goes on naturally in frogskin—and again here is a natural environment which has been explored considerably from this point of view in the transport of sodium and chloride across the frogskin—a frog does not concentrate the salt. The frog expends somewhere between 3 to 6 watt-hours per gallon of sea water, which would have been rendered free of sodium and chloride. This compares quite favorably to the theoretical minimum. Hence the interest, the basic interest, in this process, of course, would be to find out whether or not we could ever learn enough to be able to apply some of these very considerable efficiencies.

The initial report concluded that the present state of knowledge is not nearly far enough advanced to be able to make a synthetic

or artificial application of these natural processes. However, it did cite the possibility of using complete organisms to try to harness them to do the job. The organism that was explored theoretically was the lowly algae, some species of which do concentrate sodium and chloride some severalfold, and some actually do several hundredfold times the environment in which they grow. There are some algae, for instance, which are known to concentrate potassium as high as 4,000 times the environment.

A recent article in Science, I think last week's Science there was a concentration of potassium and calcium to a reference of about 1,700. But these processes do go on in the algae.

I was unable to find a complete literature breakdown on all the species. Obviously there is lots of work yet to be done to get at the bottom of this process, or even to catalog it. The process that was propounded is the one shown on this diagram which was passed out, figure I of the proposal, which would show sea water coming into this basin where an electrosuspension would be grown under optimum conditions for the uptake of the salt. So these algae would take up the maximum amount of salt they could out of the salt water and would be separated from the water by some mechanical means of separation, some of which are in practice in some of the experiments in which algae are being grown for food. Then the algae would be placed in a second basin and there the conditions would be such that the algae would not be able to metabolize optimally. Therefore they would be denied some of the energy required to maintain the internal concentration of the salt and it is hoped that the salt would be secreted by the algae and come out of the algae as the concentration approached equilibrium with this second basin water, which would also be sea water. The algae thus would have removed some salt from the first basin and deposited it in the second. It would be picked up and recycled, the algae would, in the first basin, which would be a reversible process, without permanently damaging the algae, and pick up another load of the salt and go to the second basin, where this in turn would be released.

The calculations, again based on the limited data available in literature, would indicate that 25 gallons of this algal suspension might be able to produce one gallon of fresh water from sea water per hour. If anything like this could be achieved in reality I think it might have very practical applications. It is not a bad return at all.

Of course, there are still many problems in growing algae, but these are being tackled by a number of people who contend algae is the future food source of the world to contend with the population explosion. The Carnegie Institution concluded in a study that it will be feasible to grow algae in mass cultures.

On the basis of this report we proposed to the Office of Saline Waters a laboratory investigation of this potention method, and it is a very simple investigation. It is not known at the present time whether algae indeed could be induced to give up the salt they had concentrated. This is a simple experiment which we have proposed which would merely find out whether or not the algae would give up the salt that had been so concentrated, and at what rates this might occur. This is then a feasible study of the method. If this first

stage looks good it might be worth while to go on and explore it in greater detail.

Mr. JONES. Then you mean it is a proposal you have made on behalf of your organization to the Office of Saline Water for an experiment?

Mr. LEVIN. That is correct, sir.

Mr. JONES. Yes.

Mr. LEVIN. This probably has been a bit rambling, but what I want to point out mostly is, this physiological field of ion transport, while it may seem in the distant future insofar as any practical application to the saline water problem is concerned, I think nonetheless should be investigated for the mere reason that the natural processes are able to contend with this problem, and have been since life first existed, with a relatively high efficiency.

I would like to go from this just to make some general comments on the saline water conversion program as a whole. I think the program has not been given its due recognition for its true importance. I think this could be said for it is important domestically and internationally. It would seem to me that the availability or the proffering of a method whereby fresh water could be extracted from the sea would have a tremendous impact not only in our own country, where we well know many areas would immediately profit, but in our foreign relations with other countries, particularly in the Middle East.

I feel should the Russians, for instance, beat us to this, it may be in the realm of another sputnik that they can suddenly offer a method to these people for whose support we are competing, to get water on the desert. That would be a very excellent argument. I think from the standpoint of the view of the importance of the program, the total funds available have been very, very small. In terms of what amount of these funds should be designated for basic research, I heard some discussion on that the other day and I think there were some misunderstandings as to basic research, because a statement was made that I think most people agreed to some level of 10 to 12 percent of the total funds should go to basic research, but a statement was made once a breakthrough occurs we should then put more funds to the task of exploiting this breakthrough. Once a breakthrough occurs, you are no longer dealing with basic research. Where you have to put the basic research emphasis is in trying to develop a breakthrough.

At this point I do not believe we have yet had a breakthrough in the saline water conversion field.

There are processes which are being developed which will have application to specific problems and in specific areas, but I think that for the basic research part of this program, should there be increased funds available, a large portion of those increased funds should go to basic research, in trying to get to the point where we obtain a real breakthrough.

I tend to regard a lot of the mechanical applications, and heat applications, as being a brute-force method, because as long as you have to supply that latent heat of evaporation, it is going to take a lot of energy. Therefore I would not recommend, if increased funds are given, that very large shares of these funds should be for the erection and operation of prototype units. I do not think we are far enough along here to warrant large prototypes.

I think that is about the extent of my statement.

Mr. JONES. Thank you very much, Mr. Levin.

Mr. Fascell.

Mr. FASCELL. I have no questions, Mr. Chairman.

Mr. JONES. Mr. Brownson.

Mr. BROWNSON. Is there any temperature problem in the culture and preservation of these algae? Do they operate and grow under a wide range of temperatures, or do they have to be cultivated under a controlled-temperature situation?

Mr. LEVIN. The temperature does affect their metabolism. I do not know how narrow the proportion of the range is, but it might be a band of 5 or 10 degrees in which they can get optimum results. It might be necessary, for instance, to maintain and control temperature in order to prevent or to promote metabolism, but it should be easier to regulate the temperature within a few degrees than to distill water.

Mr. BROWNSON. Thank you.

Mr. JONES. Mr. Knox.

Mr. KNOX. I have no questions, Mr. Chairman.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. Does the algae separation of salt require sunlight?

Mr. LEVIN. Yes; it would require sunlight.

Mr. INDRITZ. Would it require any other kind of energy?

Mr. LEVIN. The other energies would be derived from trace elements and nutrients which would be present in the water. For instance, in California they are doing extensive work in utilizing algae to treat sewage by means of utilizing the sunlight, and the trace minerals present in the sewage, to incorporate the undesirable nutrients, that is, undesirable from the point of view of being discharged into the stream, into the algae, and thus removing them.

Mr. INDRITZ. So if the process you have described were to be successfully applied, it would utilize free energy such as sunlight, and the only energy from fossil fuels or other types of fuels would be that required in shifting the algae from one basin to another, so that the algae method would have the advantage of conserving fuels which might otherwise have to be used in such methods as electrodialysis and distillation; is that correct?

Mr. LEVIN. That is correct. It may be to obtain the desired conditions certain amounts of nutrients would have to be added, but this is of a small order indeed and it might be dovetailed with a sewage treatment process, for instance.

Mr. INDRITZ. Would the amount of energy required for moving the algae from one basin to another be so large as to outweigh the benefits of the use of free energy?

Mr. LEVIN. No; this would be very, very small.

Mr. INDRITZ. What would be the cost of building the ponds or basins to hold these large quantities of water?

Mr. LEVIN. This would be an initial capital investment not unlike the initial investments in similar basins in water treatment plants and sewage disposal plants. They amortize very well over a long period of time.

Mr. INDRITZ. And if the cost of such amortization were included in the cost of the product water, of what order would that be?

Mr. LEVIN. In terms of price?

Mr. INDRITZ. Yes.

Mr. LEVIN. I would not want to hazard at this point.

Mr. JONES. That is part of the purpose of the investigation, as I understand it. Is there anything further?

Mr. INDRITZ. No, sir.

Mr. JONES. Thank you very much. It has been a pleasure to have you, sir. The text of your paper on laboratory evaluation of the use of algae in saline water conversion will be inserted in the record at this point.

(The document referred to is as follows:)

PROPOSAL FOR LABORATORY EVALUATION OF USE OF ALGAE IN SALINE WATER CONVERSION

On the basis of its report Survey of Physiological Mechanisms of Sodium and Chloride Ion Transport and Design of Experiment for Application To Demineralizing Saline Waters submitted to the Office of Saline Waters October 1957, Resources Research, Inc., proposes to undertake a 6-month laboratory investigation of the feasibility of utilizing algae to convert saline waters. The project would not attempt to develop the full process proposed in the report, but would merely test the fundamental concept upon which the process is based.

OBJECTIVE

The objective of the proposed project is to determine whether algae which are known to accumulate internal concentrations of salt in excess of the concentrations in their environment will secrete salt when their metabolism is inhibited.

BACKGROUND

In October 1957, Resources Research, Inc., completed a project for the Office of Saline Waters under contract No. 14–01–001–96, entitled "Survey of Physiological Mechanisms of Sodium and Chloride Ion Transport and Design of Experiment for Application To Demineralizing Saline Waters. Resources Research, Inc., had proposed the study on the basis that a review of the natural processes by which living organisms are known to separate sodium chloride and water might reveal potential engineering applications. The work consisted of a literature search in the fields of medicine, physiology, biochemistry, and related disciplines.

Ion transport in human and animal kidneys, intestinal mucosa, secretory glands, amphibian skin, fish, plants, and individual cells was reviewed. These and all other living organic material constantly accumulate and excrete salts, including sodium chloride from aqueous solution. This is necessary in order to maintain vital electrolyte balances. On the basis of current information, there seems to be a striking similarity in physiological mechanisms that effect this action. Factors in common with many varieties of animals, plants, and cells are the abilities to accumulate and maintain ions against considerable concentration gradients through the expenditure of energy derived from metabolic processes. This process is universally performed at the cellular level. Although special organs, such as the kidney, may conserve ions within the organism, the ions must then be distributed throughout the cells. The intercellular fluid contains concentrations of selected ions at levels many times that of the extracellular fluid. In order to obtain and maintain this condition, the cell must expend metabolic energy at the cell wall.

The ability of isolated frog skin to transport sodium chloride from its outer to its inner side has been studied for many years. The action is typical of physiological transport in that the sodium and chloride ions are moved in a direction against the concentration gradient, that its, the ions are transported from the less saline outer solution to the more saline inner solution. Metabolic processes continue to supply energy for the process in the isolated skin for several hours. More data has been obtained about transport in frog skin than most, if not any, other organic materials. It has been reported[1] that the energy expended by

[1] Zerahn, K., Acta Physiol. Scand., 36: 4, 1956.

frog skin is 1,340 to 2,680 grams-cal per equivalent of sodium transported. The chloride follows the sodium passively in order to maintain electro-static balance. The power required to desalt 1 gallon of 30,000 parts per million NaCl sea water in 1 hour may be calculated:

NaCl content of sea water=113.5 gm/gal
This is 113.5/58.5=1.94 equivalents NaCl
Energy required=1.94×1,340=2,600 gm-cal
Which, if expended in one hour, would be 2,600×0.00116=3.015 watt hr/gal for the lower energy value reported and 2×3.015=6.030 watt hr/gal for the higher one

These energies are much closer to the theoretical minimum power requirement of 2.8 watt-hour per gallon of sea water desalted than are the energy requirements of any existing or proposed conversion process.

An average rate of sodium chloride transport through frog skin as determined from several references[2,3,4,5,6] is approximately $50 \times 10^{-6}$ gm./hr./cm.$^2$ The surface area required for complete desalting in 1 hour of 1 gallon of sea water containing 30,000 part per million sodium chloride can thus be calculated:

NaCl content of sea water=113.5 gm./gal.

$$\frac{113.5}{50 \times 10^{-6}} = 22.7 \times 10^5 \text{ cm.}^2 = 227 \text{ m.}^2 \text{ required}$$

While this is a prohibitively large surface area requirement for the use of any continuous surface in one plane, large surface areas per unit volume are available in finely divided material. Such finely divided organic material that conduct active transport of sodium and chloride are unicellular algae. Some unicellular algae are known[7] to accumulate sodium and chloride ions to concentrations considerably exceeding that of their environment. The source of energy for the physiological transport of the ions, sunlight, is free. Unicellular algae can be grown in mass cultures.[8]

Since it has been found that ion transport processes in different organisms are quite similar, for the purposes of rough approximation it is assumed that the energy-surface ratio for transport in algae is of the order of that in frog skin. On this basis, the quantity of algae necessary to supply the required surface area may be estimated.

Algae suitable for the purpose at hand might possibly be found in the size range of *Chlorella*. A steady state culture of *Chlorella* may contain approximately two cubic millimeters of cells per milliliter of suspension. Assuming the cells to be cubes, a simple calculation may be made giving the approximate cell surface area contained in one gallon of suspension:

Surface area/cell=150 microns$^2$
Volume/cell=125 microns$^3$

$$\text{One ml of suspension contains } \frac{2 \times 10^9}{125} = 1.6 \times 10^7 \text{ cells}$$

This is $1.6 \times 10^7 \times 150 = 2.4 \times 10^9$ microns$^2$ of surface=$9.08 \times 10^{12}$ microns$^2$/gal. suspension=9.08 m$^2$, and 227/9.08=25 gallons of suspension are required to offer sufficient surface to remove all the sodium chloride from 1 gal. 30,000 ppm NaCl sea water in 1 hour.

Thus, if an algae approximately the size of *Chlorella* were found to have the necessary characteristics, the surface area requirements would be fairly easily satisfied.

In its report[9] to the Office of Saline Waters, Resources Research, Inc., proposed a method of utilizing algae for the conversion of saline waters. The method incorporated the unique feature of recycling the algae in order to reduce the quantity of algae that must be handled and to eliminate the generation time required for the production of fresh algae.

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[2] Huf, E.; Wills, J.; and Arrighi, M., J. Gen. Physiol., 38: 6, 1955.
[3] Linderholm, H., Acta Physiol. Scand., 27, Supp. 97, Uppsala, Sweden, 1952.
[4] Ussing, H., Acta Physiol. Scand., 23: 110–117, 1951.
[5] Op. cit., 1.
[6] Leaf, A.; and Renshaw, A., Biochem. J., 65: 82, 1957.
[7] Osterhout, W. J. V., Bot. Revs., 2: 283, 1936.
[8] Algal Culture from Laboratory to Pilot Plant, Burley, J. S., Ed., Carnegie Institution of Washington Publication 600, Washington, D. C., 1953.
[9] Levin, G. V., of Resources Research, Inc., Washington, D. C., Survey of Physiological Mechanisms of Sodium and Chloride Ion Transport and Design of Experiment for Application to Demineralizing Saline Water for Office of Saline Waters, U. S. Department of the Interior, October 1957.

A species of algae with the desired characteristics would be grown in a basin of saline water under conditions to promote maximum incorporation of sodium chloride. The algae would be continuously removed from this basin by mechanical means and introduced into one end of a second basin of the water. Now, almost without exception, investigators in the field of physiological transport of ions agree that the continued expenditure of metabolic energy is a requisite for the maintenance of high internal concentrations of ions. Furthermore, it is generally believed that sodium is not bound inside the cell, but, where stored against the concentration gradient, it would be free to diffuse out were energy not expended to keep it in the cell. Chloride plays no part physiologically, and would also be free to diffuse across the cell membrane. Therefore, it is proposed to inhibit the metabolism of the algae in the second basin. It is possible that this may be accomplished merely by excluding light and interrupting photosynthesis. Other possible reversible means of denying energy to the cells might be by reducing the temperature below the optimum or by the use of antimetabolites. Most theories indicate that the algae should secrete salt under these conditions as the intracellular sodium chloride concentration approaches equilibrium with the environment by means of diffusion. The salt removed from the first basin would thus be dumped in the second basin. The algae would then be mechanically removed from the second basin and returned to the first. Again under optimum conditions, the algae would pick up another load of salt. As the cycle continued, the sodium chloride content of the first basin would be depleted. As the algae were separated from the effluent of the second basin, the salt enriched water would be discharged to waste and additional saline water from the source let in the influent side of the basin.

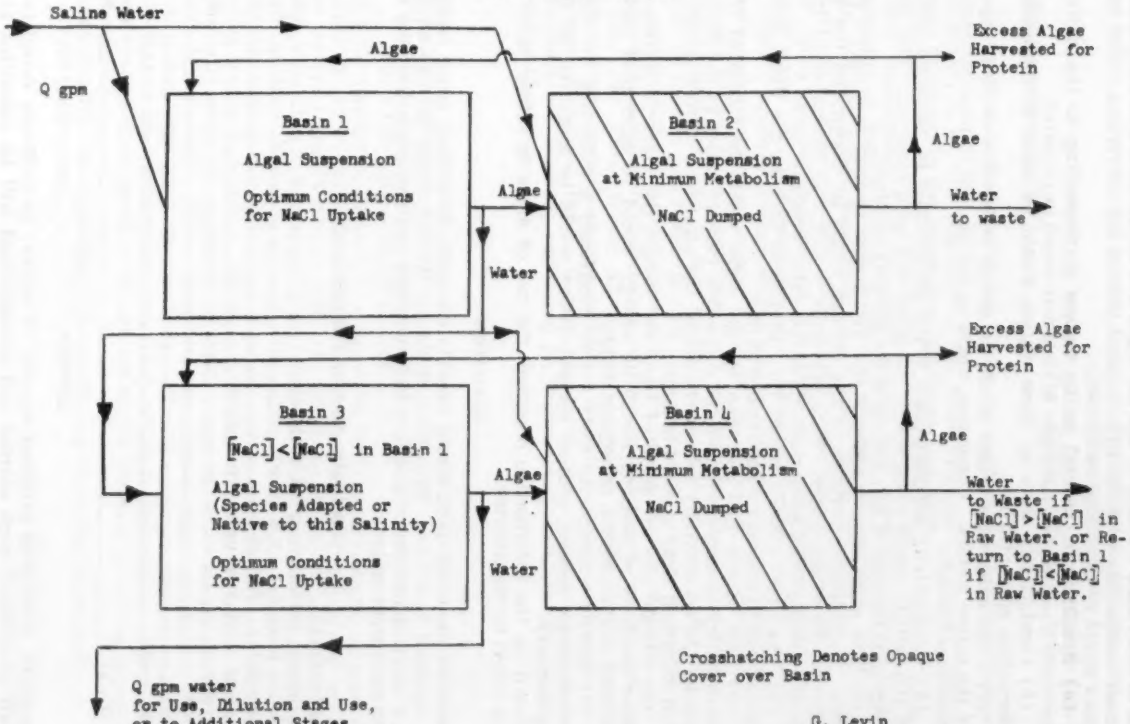
While some algae can acclimate to a considerable range of sodium chloride concentrations, it may be necessary to operate several sets of basins in series with a different algal culture in each to reduce the sodium chloride content of the product water to the desired level step by step.

Figure 1 shows a flow diagram for the proposed process.

It might be pointed out that biological processes are commonly used in processing large quantities of liquids such as sewage and beer. In the case of the former, individual activated sludge plants may handle as much as several hundred millions of gallons of sewage per day. A process producing the previously calculated one gallon of fresh water per hour for each 25 gallons of process material would present a favorable quantitative aspect for industrial-size application. This ratio of product to process material is based on desalting sea water. The ratio would be more favorable in the case of brackish water.

The principal question to be resolved in developing the proposed method is "Will the algae secrete the salt they have accumulated when they are deprived of their source of energy? A careful search of the literature has revealed no report on laboratory work of this nature. There is much evidence that the algae accumulate the salt, but whether or not they will give it up again is apparently unknown at present. Most of the accepted theories of ion transport by physiological processes indicate they should.

FIGURE 1.—FLOW DIAGRAM FOR HYPOTHESIZED USE OF ALGAE IN SALINE WATER CONVERSION SHOWING TWO-STAGE PROCESS




G. Levin
Resources Research, Inc.
Washington, D.C.

PROCEDURE

1. A selection of various types of algae whose known characteristics are favorable for the use intended would be made.

2. Pure cultures of these algae would be obtained, and laboratory tests conducted to determine whether or not the algae will accumulate and secrete salt in a manner compatible with the hypothesized process for converting saline water. The tests would be conducted as follows:

(*a*) Synthetic or natural saline waters corresponding to the native or acclimated habitats of the algae to be tested would be prepared.

(*b*) Conductivity tests of these waters would be made to establish the electrolyte concentration.

(*c*) Pure cultures of algae would be grown in beakers or small aquaria of the saline waters. Conditions would be maintained to promote optimum growth of the cells.

(*d*) Conductivity measurements would periodically be made on portions of the culture water from which the algae had been removed. This would determine the rate of salt uptake in the growing culture.

(*e*) The algal culture under study would then be kept in complete darkness. Periodically, portions of the culture would be drawn and the algae removed from the water. This operation would also be conducted in the dark. Conductivity measurements of the water would be made.

(*f*) The algal culture would then be placed back in the light, and the rate of salt uptake again determined as in *d*.

(*g*) Salt uptake and secretion by the algae would be indicated if the conductivity measurements of the algae-free culture water in the dark exceeded the conductivity measurements of the algae-free culture water that had contained algae exposed to light.

(*h*) Should the exclusion of light not induce the algae to secrete salt, other methods of denying metabolic energy would be attempted such as chilling or the addition of antimetabolites.

(*i*) Should conductivity tests not be completely satisfactory for the determinations desired, sodium concentrations would be measured by flame photometry.

3. Based on the information obtained, the use of algae in saline water conversion would be reevaluated.

FACILITIES

Resources Research, Inc., would provide adequate laboratory space equipped with standard facilities. The Office of Saline Waters would furnish an autoclave, a spectrophotometer, a still, a galvanometer and two potentiometers from surplus equipment on hand.

*Cost estimates for 6-month project*

| | |
|---|---|
| Staff personnel: | |
| Principal investigator (1/6 time) | $1,000 |
| Senior biologist (1/3 time) | 1,500 |
| Technician (full time) | 2,500 |
| Retirement, social security, insurance | 350 |
| Equipment | 2,000 |
| Supplies | 800 |
| Travel | 800 |
| Indirect costs | 800 |
| Total | 9,750 |

REPORTS

Bimonthly, letter-type progress reports (6 copies) in sufficient detail to disclose all substantial work started and accomplished will be submitted at the end of the second and fourth months.

A final report (20 copies) covering all work under this proposal will be submitted on or before the completion date of the contract.

PAYMENT

Three thousand dollars will be paid upon approval of the contract. Two thousand two hundred and fifty dollars will be paid following receipt of each of the two progress reports. The final payment of $2,250 will be made following receipt of the final report.

RESOURCES RESEARCH, INC.,
By GILBERT V. LEVIN,
*Principal Investigator.*
By LOUIS C. MCCABE, *President.*

Date: November 27, 1957.

BIOGRAPHICAL SKETCH OF PRINCIPAL INVESTIGATOR GILBERT V. LEVIN

Education: B. E., civil engineering, the Johns Hopkins University, 1947; M. S., sanitary engineering, the Johns Hopkins University, 1948.

Professional experience: Maryland State Department of Health, bureau of sanitary engineering, 1948–50, water supply and sewage disposal; California Department of Public Health, bureau of sanitary engineering, 1950–51, water supply, bathing water sanitation and sewage disposal; District of Columbia Department of Public Health, 1952–56, water-pollution control, sewage disposal, water supply; Resources Research, Inc., 1956——, consulting sanitary engineer in fields of water supply, sewage disposal, industrial wastes disposal, stream pollution control, sanitary biology, saline waters and related environmental subjects.

Additional relevant material: Invented rapid means for detecting coliform organisms by use of radioisotopes (this research was supported by the Atomic Energy Commission and is now supported by Public Health Service grant); member of faculty and research staff of Georgetown University School of Medicine; approximately 10 publications in field of sanitary engineering and sanitary biology; member of Federation of Sewage and Industrial Wastes Association, American Water Works Association, American Public Health Association, Maryland-Delaware Water and Sewage Association, American Society of Civil Engineers, Municipal Public Health Engineers, American Association for the Advancement of Science; registered as professional civil/sanitary engineer in District of Columbia.

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RESOURCES RESEARCH, INC.,
*Washington, D. C., April 30, 1958.*

Congressman ROBERT E. JONES,
*Chairman, Subcommittee on Public Works and Resources,*
*House Office Building, Washington, D. C.*

DEAR CONGRESSMAN JONES: In connection with my testimony at your recent hearings of the Public Works and Resources Subcommittee on the subject of saline waters I should like to make the following statement supporting my expressed view that the proportion of funds expended for basic research should exceed the 10 or 12 percent generally recommended by other witnesses.

It is my feeling that there has been no significant breakthrough in the field of saline water conversion. If the conversion of saline waters is to compete economically with the provision of fresh water by other means such a breakthrough is necessary. It is, therefore, my opinion that considerable basic research is indicated as a first priority. Should appropriations to the Office of Saline Waters be substantially increased, which in my opinion is warranted, I believe that as much as 25 to 40 percent of the increase should be expended on basic research.

Thank you for this opportunity to amplify my views for the record.

Very truly yours,

GILBERT V. LEVIN,
*Sanitary Engineer.*

Mr. JONES. Our next witness is Mr. John I. Yellott, executive vice president of the Association for Applied Solar Energy of Phoenix, Ariz.

We are glad to have you, Mr. Yellott.

## STATEMENT OF JOHN I. YELLOTT, EXECUTIVE VICE PRESIDENT, ASSOCIATION FOR APPLIED SOLAR ENERGY, PHOENIX, ARIZ.

Mr. YELLOTT. Thank you, sir. It is a pleasure to be here.

Mr. JONES. You may go ahead, Mr. Yellott.

Mr. YELLOTT. Thank you very much, Mr. Jones. I have prepared a statement because it looked to me like that was the best way to get this particular information in the hands of you gentlemen and also of the press.

In response to your letter, what I did was to dig into the records of our association to try to see what I thought would be of the most help. I find it is very difficult for most people to understand the fundamental problems in trying to get what should be something for nothing on this so-called free energy of the sun.

I have put together here some information and also a chart which shows the climate in a typical arid area, in other words, Phoenix, Ariz., which is typical of those arid areas in the world that we are trying to find some means of supplying with water. This is a chart that we put together a year ago literally in planning for this solar house to tell us just how much sunshine there was in this area, and what the temperatures were, and how many hours of sunshire there were a day, and the intensity of the sunshine throughout the year. I think it is enlightening to realize there is roughly a 3 to 1 variation in the intensity of sunshine as shown by the chart entitled "Climatological Data, Phoenix, Ariz., 1956."

Likewise there are some fundamentals of this business which must be understood in trying to grasp the real difficulty of the problem. One of the witnesses yesterday compared the difficulty of this problem to that of making power from the atomic fission process. That is truly the case. It was my good fortune to be associated in the early days of that actually with the power aspect at the University of Chicago, and 10 years and billions of dollars have been spent and the first few kilowatts are just beginning to flow now. We have not yet made the transition from what I would call the pilot stage in that process to the full-scale commercial stage. Certainly hundreds of times more money has been spent.

There was discussion yesterday, and again this morning, of solar stills, and I think it is well to remember that 90 years ago there was quite an effective solar still. I had put in the record all of that as the first section of this statement. The only complete report on the performance of this still at Las Salinas in Chile in 1872 was available in the library of the Solar Energy Association.

A civil engineer named Josiah Harding presented a paper on that subject in 1883, and it is interesting to realize in the 90 years which have elapsed since that still was built there have been few, if any, major improvements. In other words, the fact that we have now plastic materials which give promise of having long life in the presence of intense sunshine is the only really major improvement we have made.

Dr. Telkes has improved the unit output of small stills to a very marked extent, but no one really has come up with a big one, which is a marked improvement on the one that they ran at Las Salinas, Chile.

The facts of economic life in Chile in 1872 were quite simple. They were paying 4 cents a gallon for drinking water. These prices are so far out of line with the price we have been talking about that they are hard to conceive of. But if you have been in the arid areas of the world you realize there is no price that you can put on water which is too high if you do not have it.

So this still at Chile was put together for a specific purpose, and it did the job until a new means of acquiring water was found, namely, a narrow-gage railroad with tank cars that came along. The price of the water was cut thereby and the still fell into disuse. To the best of my knowledge, no one has contemplated one that big since.

The fundamental factors in regard to the production of fresh water from salt water by any solar process we know at the present time are very simple. A farmer in central Arizona, for example, would have to use something like one-third of his farm for a solar still in order to produce the 2 acre-feet he needs to irrigate his land. So that is why the need for a breakthrough, which has been mentioned several times, is of the utmost importance.

We can make drinking water now by solar stills at prices which are comparable to those paid, let us say, in Key West, Fla. I had the pleasure last year of demonstrating such stills in Greece. I went over with a mission for the International Trade Fairs Office. Next week we will do the same thing at Casablanca, Morocco. However, these are strictly drinking-water devices, like the type developed by Dr. Telkes working for the Office of Saline Waters. They are very effective in small size and can make drinking water and the costs, of construction and maintenance are not exorbitant, but we have not come close by a factor of 100 to 1 to producing irrigation water.

In one of the paragraphs here I give the facts of what a farmer in the Phoenix area now pays for irrigation water. It is so cheap that no process by which he must make a large capital investment can compete with it.

This year the members of the Salt Water River Users Association will be entitled to a third acre-foot, because last year we had fairly good rainfall in the watershed. They will pay an additional $3.75 for that acre-foot, which is considered a high price for irrigation water in central Arizona.

The fundamental problem with solar distillation has already been mentioned, because if you must absorb the latent head of a pound of water and throw it away again by condensing it, it is inherently a very inefficient process, but that is almost the only way we know how to do it.

Our association, a quite small privately financed scientific organization with membership over the entire world, at present is working on a very modest project which we think will show a marked improvement. That is mentioned on page 3 of my testimony.

There is a company in Italy which produces a pump which is run by the sun. Strangely enough, this is the only power device you can purchase anywhere in the world today run by solar energy. There has been a great deal of talk about it.

Fifty or sixty years ago there were some other attempts, but only one, a device of a 1-horsepower motor that runs from the sun, is used now. We have one at Phoenix, or the adjacent city of Tempe, Ariz., and we are going to put together in cooperation with the Arizona State College at Tempe a vapor compression still proposition which will operate in accordance with the principles which have already been outlined, but using a solar pump to supply the power. When we condense the vapor which runs that pump, that will start the vapor compression process by giving us the first pound of vapor we need. It looks like that can make a difference of about 5 to 1 in the amount of area required to produce, let us say, 1,000 gallons of water. But it is only by taking such, let us say, abrupt changes from past methods, that we are going to find an answer to this.

Mr. Levin talked about the algae method. Certainly nature has done a far better job than we have. I was not aware of the performance of frog skin, but I certainly know in our own skins we can excrete salt effectively, as you realize when your own cat or dog comes up and licks your hand. He is not only demonstrating love, but getting salt from you. We do not know of any process which can do it anywhere near as cheaply as nature can.

One of the things our association has done is to look into a method of long-range weather prediction which Dr. Charles Abbott, for many years Director of the Smithsonian Institution, propounded. This was brought to our attention a year or so ago, when Dr. Abbott visited Phoenix, Ariz. His results in correlating long-range weather predictions with the actual event appeared so striking that several of our members asked him to undertake the study for setting up a weather station in the Phoenix watershed. Literally we in Phoenix do not pay much attention——

**Mr. JONES. May I ask you a question there?**

Mr. YELLOTT. Yes, sir.

Mr. JONES. Does not the Smithsonian have a research program they conduct out of Phoenix?

Mr. YELLOTT. No. Their measurement of solar energy is at Table Mountain, Calif. That is the only one I am aware of that is out there.

Mr. JONES. My recollection is we used to appropriate about $1 million a year for that solar energy work.

Mr. YELLOTT. That is for measurement of solar intensity and fundamental study of the activity of the sun.

**Mr. JONES. Go ahead. I did not mean to interrupt.**

Mr. YELLOTT. Yes. Dr. Abbott's method of long-range prediction is a statistical one. For 30 years he was responsible for measuring or supervising measurements of daily intensity of solar energy, and he found a consistently very small, but still measurable, variation in the sun's output. In looking about to see what other things had somewhat the same periodicity, he found both precipitation and temperature at specific locations seemed to follow the same general pattern. He went to work and followed out his method for certain places, such as St. Louis and Peoria, which are regions blessed with relatively abundant rainfall. His method of predicting appeared to us to have a considerable amount of merit to it. It is strictly statistical and a long-range estimate which we in central Arizona like,

because our rainfall occurs in our watershed in the mountains to the north and east of Phoenix. In Phoenix if we get 7 inches of rainfall it is a lot. It is enough to lay the dust, and that is all. It usually comes in spurts, too, when it comes, running on down, and does little good.

All the rainfall by which we live is in the mountains, which give the water to the Salt River and the Verde River. So Dr. Abbott selected a station at a place called Natural Bridge, which is little more than that. There is a natural bridge there. It has had a weather station there since 1890. He applied his method of long-range predicting to the data gathered from Natural Bridge, and he got a certain correlation between the actual event and his forecast.

Dr. Abbott's original method was done entirely by hand. In other words, the system was done in longhand calculations and was a very laborious one. When we showed it to the mathematicians at Arizona State College, who are fortunate enough to have at their disposal one of these giant electronic brains, they said, "This thing can be programed and the work which has taken months to do can be done now in minutes." So that is being done for 30 other weather stations throughout the country.

The significance of this is simply this: In order to predict what we will need in the way of additional sources of fresh water in various parts of the country we have to have at least some faint idea of what nature will give us. That is why we are so interested in this proposition for central Arizona. It seems as though Dr. Abbott has some validity to his method. He is most cautious in pointing out that this is strictly a statistical matter and he cannot tell how much it will rain in any one month, but he can reasonably closely come up with the trends.

For example, in 1956 we had a very severe drought in central Arizona, and had the drought continued 1 more year our farmers would have been in a bad way. Fortunately, 1957 reversed the trend and 1958 is going even further in that direction. So what we think we have accomplished by this method is to bring at least one more fact to bear on this extremely important subject. Certainly the only process by which fresh water is produced now from salt water is by the use of solar energy from the sun itself, just as the sun does it every day, and it looks like Dr. Abbott made a major contribution by enabling us to predict what it is likely to produce in any given area for a long period in the future.

Mr. JONES. Mr. Fascell.

Mr. Yellott, he is from Florida, where they have a lot of sunshine, too.

Mr. FASCELL. I assume there is sufficient condensation out of the oceans of the world, but the problem is the proper distribution.

Mr. YELLOTT. That is exactly the problem, as far as we can see.

One other institution I would like to mention also in Arizona is the Institute of Atmospheric Physics in the University of Arizona. They are trying to find out what makes rain fall from the sky, and what stops it from falling. The reason for that is because across central Arizona each summer comes a tremendous stream of vapor-laden air, but it just keep on going. The problem is, How can you make it come down where you want it?

Everyone will admit we have not yet found the answer to that. Of course, all of the water we get in the form of fresh water comes from the oceans. Nature distills it through the process of the sun's energy and brings it back down again, but unfortunately we have not been able to learn how to control that.

Mr. FASCELL. Of course, it is basically the simplest process.

Mr. YELLOTT. Yes.

Mr. FASCELL. And the cheapest.

Mr. YELLOTT. It is the cheapest because it requires no capital investment. We would not begin to know how to make the investment.

Mr. FASCELL. So it might be wise for us to spend a little bit of our money to find out how to control the weather.

Mr. YELLOTT. There is a lot of work going on in that direction, and certainly when we talk about breakthroughs, if the Russians were to accomplish that, it would be terrific.

Mr. FASCELL. And, of course, we are working on it.

Mr. YELLOTT. Yes, we are working on it, and apparently there is a lot of classified work in that field. I hear rumors of it, but no substantiating facts.

I would like to second what Mr. Levin said a few moments ago about the importance of this fresh-water business in the Middle East, because with one trip to Greece over and another to Casablanca, Morocco, coming up, I can see how vitally important it is on the islands of Greece, which most of us tend to think of as being as green as this tablecloth, whereas they are as arid as the hills of Arizona, and as brown. The Mediterranean has very few rivers which pour down into it, and these islands are very arid.

The kind of water-producing system developed under Mr. Jenkins' program was shown to the Greeks at a trade fair last year, and is being built by a company in Athens and being used to provide drinking water for the islands off the coast of Greece. We hope the same thing will happen in Morocco as a result of the demonstration next week.

Mr. FASCELL. May I ask another question?

Mr. JONES. Yes, go ahead.

Mr. FASCELL. My curiosity is aroused. Why would it not be possible to intercept the condensation of the ocean and pipe it where you want it?

Mr. YELLOTT. I do not think at the present time we have the faintest notion how to start on that problem. We have tried cloud seeding, which is one way of doing the same thing.

Mr. FASCELL. I did not mean that. Let us say you laid plastic sheets within a certain distance of the water itself. Would that be possible?

Mr. YELLOTT. I might term it another way. When I mentioned at the beginning the only major improvements in solar stills had been in the use of plastic films instead of glass, that is, of course, one of the thoughts behind those plastic stills that whatever natural precipitation comes down from the outside you catch and take it in to use it, as well as the artificial water that you create within those plastic stills. It is extremely important because they do make a reduction in the factor of 2 to 1 in the cost of water.

It is interesting to note in the experimental stills that Du Pont is running at Wilmington, when they had the great snowstorm some weeks ago, a number of greenhouses were completely destroyed because the glass was smashed flat. The solar still was also, but when the snow was melted the air pressure was applied and it came back up, and it is back at work again now. That is an interesting aspect of it.

Mr. JONES. Mr. Brownson.

Mr. BROWNSON. I have no questions, Mr. Chairman.

Mr. JONES. Mr. Knox.

Mr. KNOX. No questions.

Mr. JONES. Mr. Indritz.

Mr. INDRITZ. Could you tell us something about the original San Diego project of the Office of Saline Water on solar distillation?

Mr. YELLOTT. I can only give you what my idea is and these may not be the accurate facts. But as I recall the matter, there was to be a cooperative project in which a fairly large still, approximately 1 acre of glass and wood in a design pioneered by Dr. George Löf, was to be built. Du Pont was going to make available, also, enough of their new film to make a still of the inflated film type. What happened to that and why it did not go through I do not know. I am sure Mr. Jenkins could tell you exactly the reasons behind it. My understanding now is that the next idea is to go to your State, Mr. Fascell, and put up such an installation on the coast of Florida.

Mr. FASCELL. Hallelujah.

Mr. YELLOTT. And I believe that such a project is one of those now approaching fruition as far as the Office of Saline Water is concerned.

Mr. INDRITZ. Has your association had any contracts with the Office of Saline Water?

Mr. YELLOTT. No.

Mr. INDRITZ. Have you or your association made any proposals to them?

Mr. YELLOTT. No; because we are still a relatively new organization and do not have laboratory apparatus. This testing of the solar pump in conjunction with Arizona State College will be our first venture, aside from the solar house which Chairman Jones mentioned.

Mr. INDRITZ. Do you hope to make the results of that test available to the Office of Saline Water?

Mr. YELLOTT. Yes. We publish the only scientific journal on solar energy in the English language. The Russians have one, also, and the only thing I can remember about that is the name of the editor, because I have had correspondence with him and know his name. However, the Russians are working very busily in the field of solar energy. They have by far the biggest and best financed laboratory. They have done a considerable amount by the brute-force method of concentrating sunshine by tremendous steam boilers and using the steam in multiple-effect evaporators. That is a brute-force method.

Mr. JONES. Why do you describe it that way, as a brute-force method?

Mr. YELLOTT. Because it makes only one use of the heat. In other words, you take the 1,000 British thermal units needed to evaporate the water and use it at most once or twice, and then throw it away. In order to bring down the cost to anything like a reasonable figure we

have to do it in a much more elegant manner than that. We have to be able to use the heat at least 10 times before we throw it away. In other words, the easiest way to evaporate water is to take a teapot and put it on the burner and turn on the electricity. That is the brute-force method because you are using up and throwing away 1,000 heat units for each pound you evaporate.

That we cannot afford to do because in solar energy the cost of equipment needed to collect it is too high.

Mr. JONES. To collect the energy?

Mr. YELLOTT. Yes.

Mr. JONES. Why is it so expensive?

Mr. YELLOTT. Because of the size of it. In the middle of the winter in Arizona, and in Florida also, because we are in the same latitude, we get about 1,000 heat units per horizontal square foot per day. So no matter what you do, you cannot collect more than 1,000 heat units per horizontal square foot. You can concentrate it with a mirror, but to get 1,000 B. t. u.'s you have to have a square foot of surface.

Mr. JONES. When I was a boy I would take a glass out of a flashlight and take a board——

Mr. YELLOTT. Or the back of somebody's neck.

Mr. JONES. No; I did not do that; and I could burn my initials on the board.

Mr. YELLOTT. That is right.

Mr. JONES. That was pretty powerful.

Mr. YELLOTT. That was powerful, but it was very, very small also. If one wanted to do more than burn the letters on the board you would have had to get quite a large lens, and then you would have to go from a flashlight to an optical house, and that would cost a lot of money.

The problem is simply one of the facts of sunshine. It is very diffused. It is just as well for us that it is, because if the rays were much more concentrated we would all have been roasted to death long, long ago. But nature gave it to us in this diffused form, and the best way we know how to use it is in the form of low-temperature heat. We are not trying to convert it into power, which again brings up immediately a very large item of expense. That is what all of the solar stills in use now do, namely, collect the heat at low temperature and do it in the most economical fashion we know, but still we are not within gunshot of doing it for irrigation water. Drinking water, yes; but irrigation water, no.

Mr. FASCELL. Florida has used solar hot-water heaters for a long time. They have a lot of heat and they are very efficient.

Mr. YELLOTT. That is right; and there are thousands of them. And this new house Mr. Jones mentioned uses that new principle.

Mr. FASCELL. You put the solar water heaters on the roof of your house and you use the heat night and day.

Mr. INDRITZ. Have you or your organization studied the concentration and storage of solar energy?

Mr. YELLOTT. Yes; we have done quite a lot in both of those fields. Again the matter of concentration of solar energy is under very good control.

As an example of that, I might mention the new solar furnace which the Air Force is building at Alamogordo, N. Mex., which will give

us the greatest concentration in the world. It will give us 6 inches in diameter which will have in that particular area almost the radiation intensity of an atomic bomb, and which is completely safe because there are no harmful rays aside from the actual heat.

Mr. JONES. That is brute force.

Mr. YELLOTT. That is brute force. That is right. But as far as the storage of solar energy is concerned, we have only three ways of doing it: One, in the form of a tank of hot water, which has been done in Florida, for instance. The other is using pebbles or crushed rock; and the third is chemicals which change their state at a temperature about the level which you want to use. Those are the only three ways we know of how to do it at the present time.

Mr. INDRITZ. Do any of these four methods, namely, the concentration of sunlight and the three methods you mentioned of storing it, have any possible application to the desalinization of water?

Mr. YELLOTT. For drinking water, yes; very definitely. But we have to have a major breakthrough before we are able to predict it can be done for irrigation water. The whole thing is due to the first cost of the apparatus. At Las Salinas, Chile, as I say, they had over an acre of still, and they got 5,000 gallons per day, which was enough to keep the men and animals from dying for lack of water; but it would not have gone very far for purposes of irrigation.

Mr. INDRITZ. Have you any suggestions as to how the Office of Saline Water can advance the program of desalinization, either through the use of solar energy, or any other way?

Mr. YELLOTT. I think the program which they have underway of testing the various known ways of doing it with both glass stills and plastic stills, should be followed up, because there are practical problems that you get into in the application of these fairly large pieces of equipment which you simply cannot anticipate in advance. For example, the effect of temperature on the outside of the stills, or whether sea sand blowing along will scratch the glass or plastic and reduce the efficiency of it in that way. Those are things that we can only learn by actually doing.

I think the very small proposition which we have underway in Arizona looks quite promising, but again it is primarily for supplying drinking water for human beings or cattle and stock.

Mr. INDRITZ. Do you think the solar stills now being contemplated ought to be on a much larger scale, or is the scale now proposed adequate?

Mr. YELLOTT. I think the scale is adequate. I agree with what the gentleman said earlier. There is no point in going in and spending a lot of money for full-scale apparatus until we go through the pilot plants first, because by keeping the project vigorously alive, that is how progress will be made in the breakthrough.

As an analogy, in the generation of electricity from sunshine it was known for 100 years that you could do it by a photo-chemical process with an efficiency of 1 percent. The scientists in Bell laboratory looking for something different came on the silicon cell, which has an efficiency of 10 to 15 percent. That constitutes a breakthrough. They were not looking for a solar cell, but for a better transistor. They

were looking for a better cell and that is the reason why the Vanguard satellite is still sending out its messages.

Mr. JONES. That is very interesting. I wish I knew enough to ask you some intelligent questions.

Mr. FASCELL. There is one commercial application I know of at least and that is with respect to cameras.

Mr. YELLOTT. The electric generation of very small amounts of power is going to be very important, because every satellite that goes up in the future will have solar cells on it, and I am very much surprised that the Russians did not do that in the first two satellites, and I am very much gratified that we did when the Vanguard went up. I am sure in the space platforms being talked about, the solar cells will be used as one of the major sources of electrical power. That was a breakthrough that came because of persistent work without an immediate commercial application in mind. The men at Bell did not see that in 2 years from the date of discovery these things would be sending back messages from outer space. They could not have. Nobody would have guessed that.

Mr. KNOX. I would like to compliment the gentleman on the fine descriptive knowledge that he has of the question of saline water. I think it will be very interesting reading it. I have tried to follow him, but I am certainly not in a position to ask him any questions at this particular time.

Mr. YELLOTT. That is just as well, sir.

Mr. KNOX. But you have made a great contribution, I feel, and I think it will be very helpful.

Mr. YELLOTT. Thank you very much.

Mr. KNOX. I see you are a student of the saline water problems.

Mr. YELLOTT. It is one of the most important applications of solar energy.

Mr. JONES. The total amount authorized in 1958 was $825,000, but only $25,000 was expended for basic research. In your opinion do you think a larger proportion of the money should be spent for basic research than was spent during 1958?

Mr. YELLOTT. I would not, from my knowledge of the program, question Mr. Jenkins' judgment on that. He has done what looked to him at the time like the best possible job. This is a project which is truly comparable in magnitude to the atomic bomb project. I know how that was done bacause I was also in one small compartment of it. A great many different avenues were followed, and vast sums of money were spent. Anyone with any brightness in the entire world was recruited in the program, and finally the thing was brought off.

As far as military application goes, that is a magnificent success. Certainly as far as maritime application is concerned the cruise of the *Nautilus*, and so forth, have been magnificent successes. But it was in 1944 that we first proposed a steam powerplant by nuclear fission and the first commercial ones are going only now to operate. So it takes a long time and persistence to do that kind of thing.

Mr. JONES. Thank you very much.

Mr. YELLOTT. It has been a pleasure to be here.

Mr. JONES. You have been quite helpful to the subcommittee. Would you like to leave a copy of that magazine?

Mr. FASCELL. I was wondering if he had any descriptive literature on that solar house.

Mr. YELLOTT. By a happy chance, yes.

Mr. BROWNSON. Do you have any other copies of literature on that solar house?

Mr. YELLOTT. Yes, sir.

Mr. KNOX. Mr. Chairman, I have a commitment at 11 o'clock.

Mr. JONES. Mr. Knox, we have one more witness and we will get to him, and that will conclude our hearings.

Mr. KNOX. Mr. Chairman, I must leave because I have a commitment at 11 o'clock, but there is something I am vitally interested in. I have before me here the statement of Walter Juda, executive vice president of Ionics, Inc., Cambridge, Mass.

Mr. JONES. Mr. Brobeck from that organization is our next witness.

Mr. KNOX. Yes. If the witness is going to use Mr. Juda's prepared statement, I would make a request at this time. I have read the statement over and I know there is some criticism concerning the Office of Saline Water in this statement. Therefore I would request, Mr. Chairman, that the record be left open so that the Office of Saline Water may have an opportunity to reply to some of the statements which are set forth, principally because I think that we must have the reaction of the Office of Saline Water to the criticism if it is justified. I would request the record be left open for the replies.

Mr. JONES. Mr. Knox, it was the intention of the Chair at the conclusion of the hearing to ask unanimous consent to insert exhibits, letters, statements, telegrams, and extraneous materials that have been sent to the subcommittee by interested people to become part of the record; and, further, that the record be left open for 10 days in order that further statements could be made either in reply by the Department or their witnesses, or others interested in the problem. I will make that unanimous request now to insert those matters.

As to the identity of these exhibits, Mr. Knox, I will say that I can identify each one, but it will take quite a while to do it. I do not think too many of them are controversial or require any discussion.

Mr. FASCELL. I have no objection to the request and there is no need to identify them, as far as I am concerned.

Mr. KNOX. No. There is none as far as I am concerned either, but my objective was that in order to have a complete record we should have this opportunity.

Mr. JONES. The unanimous consent request I have made would include that right on the part of the Office of Saline Water to reply to any statement or give any statement in clarification.

Mr. KNOX. All right. I am sorry that I must leave, Mr. Chairman, but I know my colleagues here will stand by.

Mr. JONES. We appreciate your attendance during the course of the hearings. Like every other member of the committee, we have to run to and fro. It has been very difficult this year to be punctual and in attendance at all of the committee hearings.

Without objection, Mr. Yellott's prepared statement will be made a part of the record at this point.

(The prepared statement of Mr. Yellott is as follows:)

STATEMENT OF JOHN I. YELLOTT, EXECUTIVE VICE PRESIDENT, ASSOCIATION FOR APPLIED SOLAR ENERGY, PHOENIX, ARIZ.

The following statement is respectfully submitted in response to Chairman Jones' letter of March 25, in which he said that information on some of the basic problems of salt water conversion would be helpful to the subcommittee. Because the Association for Applied Solar Energy is concerned solely with the problems of using our only inexhaustible source of energy, the sun's radiation, this statement is confined to various aspects of solar energy processes for producing fresh water from salt or brackish water.

Three subjects are discussed, since it is thought that the subcommittee will be particularly interested in these aspects of the problem. The first is a record of the only commercial solar distillation plant ever set up in the Western Hemisphere. The second is a brief review of the fundamental problems of solar distillation, with a suggestion for a new line of attack. The third is a report on a new method of predicting, many years in advance, how much fresh water nature will provide for particular localities through the perpetual solar distillation process which results in rainfall.

1. SOLAR STILL OPERATED AT LAS SALINAS, CHILE, IN 1872

The largest solar still ever erected was that built in 1872 to supply drinking water for several hundred men and 4,000 mules employed in a silver mine at Las Salinas, 4,300 feet above sea level and 70 miles inland from the port of Antofagasta on the coast of Chile. The only water available at Las Salinas contained 14 percent of salts, and the cost of coal for fuel-burning stills was so high that, even in 1872, drinking water cost 4 cents per gallon.

The solar still, made of shallow black wooden troughs, consisted of 64 frames, each 200 feet long by 4 feet wide and covered by sheets of glass. The total area was 51,200 square feet, or 1.175 acres. According to the report published by Josiah Harding in the Proceedings of the Institution of Civil Engineers (vol. 73, 1883), the establishment, when new, produced some 5,000 gallons of fresh water on summer days. This yield represented about 0.81 pounds per square foot of glass and gave a water cost, including interest and maintenance, of about 1 cent per gallon. "The principal item of expense is the renewal of glass broken by whirlwinds, which are very frequent in the locality," wrote Mr. Harding.

A windmill pumped the salt water from the wells to a large storage tank, from which it flowed by gravity to the stills. Distillation usually began at 10 a. m. and continued until 10 p. m.; the water temperature in the troughs at noon was from 140° to 150° F. On cloudy days the production was less than half of that on sunny days. The total cost of the establishment was about $50,000 (1872 valuation). Major troubles encountered were leakage and insufficient cleaning, resulting in the formation of white salt crystals which cut down the still's output. The undertaking was abandoned after the opening of a railroad from the seaport of Antofagasta to the mining district of Caracoles. Water could then be supplied in tank cars at lower cost than it could be produced by distillation.

The still built in Chile nearly 90 years ago used the same principles as most of the solar stills proposed today. We have made advances in the use of plastic films instead of glass and in improved designs, but we have not yet succeeded in building a large area still which can supply irrigation water at a cost within the range of present agricultural practice. It might be profitable to look at the fundamental nature of this problem to see why, during nearly a century, no great advances have been made in such an important field.

It is also helpful to note that a farmer in the Phoenix area pays from $1 to $1.50 per acre-foot of irrigation water. Members of the Salt River Water Users Association, a cooperative undertaking, pay an annual assessment of $3 per acre, which normally entitles them to 2 acre-feet and this year will give them 3 acre-feet. This works out to a water cost of about one-third of a cent per thousand gallons (1 acre-foot equals 325,851 gallons).

Drinking water from the municipal and private systems in central Arizona costs 30 cents to 40 cents per thousand gallons.

### 2. FUNDAMENTAL PROBLEMS IN SOLAR DISTILLATION

Basically, a solar still is a device which collects solar heat in a shallow body of salt-bearing water. Some of the water is turned into vapor or steam which rises and condenses on the underside of the transparent cover which traps the sun's heat in the still. The 1957 report of the Office of Saline Water, Department of the Interior, gives an excellent account of the latest developments in solar stills including the work of such eminent authorities as Dr. Maria Telkes, of New York, and Dr. George Löf, of Denver. New plastic films developed by Du Pont are also reported, but the fundamental difficulty lies in the nature of the problem rather than in any lack of effort or ingenuity in trying to solve it.

The amount of heat required to evaporate a pound of water at 140° F. is about 1,010 heat units (B. t. u.). The amount of solar energy which falls on a square foot of the earth's surface depends upon many factors, but it is never greater than 3,000 heat units per day at sea level even in midsummer and in winter it falls to about 1,000 on clear days. A chart which accompanies this statement shows the daily amount of sunshine at Phoenix expressed in the scientific units used by the United States Weather Bureau. Multiplying these values by a factor of 3.687 gives the amount of solar energy in engineering heat units (British thermal units).[1]

Central Arizona data are given as typical of the sunshine in arid or semiarid regions where solar distillation is potentially important and practical. In midsummer, a square foot of solar still in Arizona could receive 3,000 British thermal units per day and the year-around average is about 2,000 British thermal units. If this energy could be completely used for distillation, about 2 to 3 pounds of water could be produced per square foot. The practical results in Chile showed that the actual production is likely to be closer to 1 pound per square foot of horizontal surface, which means that much of the sun's heat is not used. An engineer would say that the efficiency of simple solar stills runs from 30 to 50 percent.

Even a perfect solar still, however, would have to be extremely large to produce an acre-foot (or 325,851 gallons) of water in 6 months to give an Arizona farmer his annual 2 acre-feet. This rate of water use comes down to 1,800 gallons per day and if we use an ideal average figure of 4 square feet per gallon of daily capacity, we arrive at 7,200 square feet of surface. Since an acre contains 43,560 square feet, and the still is only 50 percent efficient, the farmer would have to devote from 16.5 to 33 percent of his acre to the solar still. At a cost of 60 cents per square foot for a still, as we know how to build them today, his investment would be about $8,500 and his annual cost would be $850 to $1,275. Thus his irrigation water would cost him about $425 to $638 per acre-foot or $1.31 to $1.97 per 1,000 gallons, and he would have to devote a very considerable fraction of his land to stills rather than to crops.

The purpose of this analysis is to show that the production of irrigation water from solar energy is a long way in the future and will require a major breakthrough which is not now in sight. The production of drinking water is a very different problem and is already within our reach.

One process which our analysis show to be potentially important is a combination of solar heating with compression distillation. A beginning has been made in this direction through a project sponsored by the Association for Applied Solar Energy at Arizona State College in Tempe, Ariz. Here a sun-powered lamp of Italian manufacture will be used to drive a vapor compressor which will operate in the manner described in the 1957 Annual Report of the Office of Saline Water. This combination gives promise of a major reduction in the size and hence in the cost of the solar heating surface required to produce a thousand gallons of water per day.

To summarize the solar distillation situation, sea water can today be converted to drinking water at a cost which is not exorbitant. Irrigation water cannot now be produced at a cost within the reach of the farmers in the arid Southwest by any available solar process and a major scientific discovery will be needed before there is any hope of doing so.

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[1] The chart referred to may be seen in the subcommittee files.

3. RAINFALL PREDICTIONS

Despite the fact that manmade solar stills have not reached the point where they can produce irrigation water, we must recognize the fact that all of our fresh water comes from the vast solar distillation process which produces rain. We are today entirely dependent upon this natural supply of fresh water, and a means of forecasting how much a particular locality will receive would be of tremendous importance.

Many years ago, Dr. Charles Abbot, then the Director of the Smithsonian Institution and the recognized leader in solar science throughout the entire world, began to study the significance of the small variations which he had found during 30 years of measurement of the intensity of the energy coming to the earth from the sun He discovered that there were very small but quite regular periodical variations in the sun's output. Carrying his correlation still further, he found that there were similar but much larger variations in rainfall and temperature in a number of locations. He then developed a statistical means of correlating rainfall for particular localities with sunspot frequency. His early work in this direction was done for regions such as Peoria, Ill., and St. Louis, Mo., which have adequate rainfall.

When his method of long-range prediction was brought to the attention of our association, two of our member companies (Arizona Public Service Co. and the Valley National Bank) suggested that he apply the method to the relatively arid region of central Arizona. Specifically, a weather station located at Natural Bridge, Ariz., in the middle of the Phoenix watershed, was selected because regular weather observation had been carried on at this location since 1890. The method of statistical analysis developed by Dr. Abbot was studied by mathematicians at Arizona State College in Tempe and the lengthy calculations of rainfall averages were programed so that they could be carried out on the electronic computing machines. The work for Natural Bridge has been completed and there is, in general, a good correlation between the amount of precipitation forecast for 6-month periods and the actual amount experienced during those same periods.

The method of calculation used by Dr. Abbot is very laborious when performed by hand but most of it can be done rapidly by electric calculators. After completing the Natural Bridge survey, the results of which are shown in the attached sheet (marked "fig. 5") Dr. Abbot and the mathematicians at Arizona State College are proceeding to process the rainfall data for some 30 other stations throughout the country. The results of this work will be available in the near future. It is our hope that these results can be used as a guide to forecast major departures from normal precipitation in virtually any part of the United States.

Dr. Abbot states specifically that his method is one for determining trends rather than for forecasting exactly what may be expected in the way of precipitation in the immediate future. We believe his method is significant for studying the relation between the water needs in any location and the amount of rain which may be expected at that same location for many years in the future.

In conclusion, we would like to state that our association has followed closely the work of the Office of Saline Water, and it is our opinion that Mr. David S. Jenkins and his staff are doing a very good job. The problem of making fresh water out of salt, in quantities large enough to be used for irrigation, is inherently difficult. It can already be done in quantities adequate for drinking water at costs comparable to current prices, but a real breakthrough will be required before we can accurately predict that irrigation water can be made by any process—solar atomic, or chemical—at prices comparable with those now being paid for agricultural water.

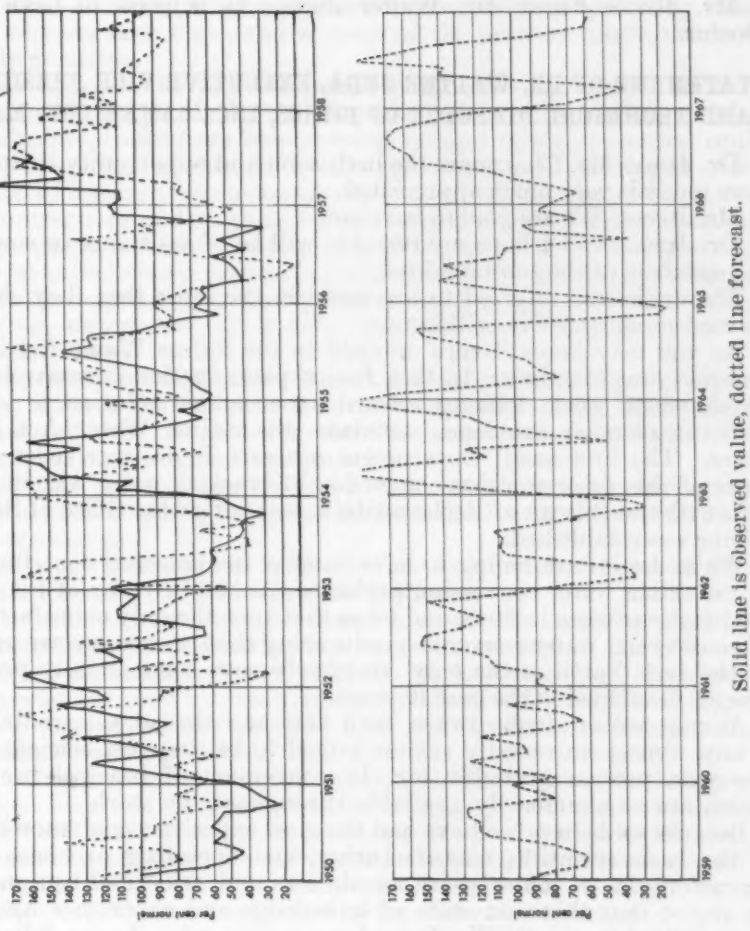


FIGURE 5.—FORECAST FOR NATURAL BRIDGE, ARIZONA; PRECIPITATION, 1950–67

Solid line is observed value, dotted line forecast.

Mr. JONES. Mr. Wayne P. Brobeck, vice president, Ionics, Inc., Cambridge, Mass.

Dr. Walter Juda, I understand, is with you.

Mr. BROBECK. If it meets with the subcommittee's pleasure, Dr. Juda is here and shall deliver it in person.

Mr. JONES. Fine. Do you have a separate statement to make, Mr. Brobeck?

Mr. BROBECK. No, sir. It will be Dr. Juda's statement.

Mr. JONES. Fine. Dr. Walter Juda. It is good to have you, Doctor.

## STATEMENT OF DR. WALTER JUDA, EXECUTIVE VICE PRESIDENT AND TECHNICAL DIRECTOR OF IONICS, INC., CAMBRIDGE, MASS.

Dr. JUDA. Mr. Chairman, the invitation and opportunity to appear here today is very much appreciated.

Mr. JONES. We are glad to have you.

Dr. JUDA. And I hope my remarks will be of assistance to you and the members of the subcommittee.

The criticisms referred to are made in the sense that they should be used as constructive criticisms.

As you may know, Ionics' interest in the Saline Water Act is direct and long standing. In fact, Ionics' participation in research and development work, looking toward an economic solution to saline water conversion problems, antedates the Saline Water Act by 3 years. The first small Government contract Ionics received on the basis of this prior work on conversion of brackish water was entered into with the Bureau of Reclamation a year before the Office of Saline Water was established.

We at Ionics are happy to have made a fundamental contribution to the saline water conversion problem. As the inventor of the electrodialysis process in 1948, and since that time the only manufacturer of commercial water conversion units using that process, we are proud of the fact that it is the only completely new, commercially proven process developed in the past 10 years.

As you are no doubt aware, both here and abroad, electrodialysis is now almost universally acknowledged to be the most efficient and economic process available for the conversion of brackish waters, which are so abundantly available throughout the world.

Because we believe we have had the most experience and knowledge of the basic scientific, manufacturing, and operating problems and characteristics of ion-selective membranes and associated equipment, we regret that this vast store of knowledge and experience has not been utilized by the OSW. Indeed, since 1955, when Ionics delivered and operated a trailer-mounted mobile unit under contract with the OSW, we have had no formal or contractual association with the Office on any new developments.

Meanwhile, the Office has sponsored research on ion-selective membranes in governmental and institutional laboratories. Most of this work duplicates the work Ionics has done years before. Even more, we note from the current report of the Office, that active efforts are being made to participate financially in duplicative research and development on membrane programs overseas. While encouragement

of worthwhile original developments abroad may be very laudatory, the expenditure of funds to duplicate existing knowledge does appear to be nonproductive.

It is not that we feel Ionics has a monopoly on all of the best ideas on membranes; it is that we have the most knowledge and experience on the subject of membranes and are therefore eminently able to effectively and economically pursue further research on the subject.

As a minimum, one would believe it logical that Ionics would be consulted to see whether or not membrane work proposed by others had already been done, and if some of the answers might not be already available.

For example, the very competent program being carried on at the Bureau of Standards in the characterization of so-called standard membranes, could have been speeded up and related to actual equipment operating conditions, by the information we developed over a period of 8 years at our own expense.

Contracts to find ways to reduce the cost of membranes have, to a large extent, rediscovered the very problems we uncovered years ago. The so-called cheap paper membranes now being talked about were made, tested, and set aside by Ionics 5 years ago for practical engineering, electrochemical production, and economic reasons, in the United States.

The one think that these research contracts and our own experience agree upon is that there will never be a really cheap, efficient membrane until the demand for them is large enough to justify high volume, mass-production equipment.

In other respects, too, we feel Ionics could have made and is ready at any time to make a substantial contribution to the overall saline-water program.

Although Ionics is best known for its work on selective ion-exchange membranes, it has abilities in other fields, too.

For example, a contract for research, development, and to pilot-plant a process for direct freezing has been entered into by the Office with an institutional laboratory in 1957. It happens that this identical idea was disclosed by the president of Ionics, Dr. Gilliland, 2 years ago in one of the most widely read and discussed technical articles on saline-water conversion.

In another case a research-and-development program being conducted by a non-Federal governmental agency, in close coordination with the OSW, uses an ion-exchange process identical with one described in a patent which our president applied for in 1953, and which was issued to the president of Ionics in January 1957.

The two basic questions raised by the above examples are—

1. How much time and money could be saved for the Government if more of an effort were made by OSW to seek the advice and assistance of those who have experience in specialized areas of interest? How much faster could progress be made if the Office had, on a full-time basis, a very few highly recognized technical men?

2. Is there some sort of a stigma attached to early and original work leading to a patent position which calls for the expenditure of Government funds to find ways to circumvent or ignore the patents obtained by original thought, hard work, and private funds?

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Another general area which Ionics feels somewhat qualified to discuss stems from our not inconsiderable experience in developing and marketing a new technological product.

The problem stems from the fact that we are a very modest-size company, manufacturing and selling small units to convert saline water. If Ionics were manufacturing mass-produced small-consumer goods, such as electric clocks, or portable radios, our standard product would have to stand or fall on being technically and economically competitive. The full market potential of such a product would have to be inherent when it is first put on the market. In the water field, the demand ranges from tiny sea-water-survival kits of a quart or so per day to multi-million-gallon-per-day plants for industry, cities, and agriculture.

Our present equipment covers only a very narrow section of this wide spectrum; namely, units producing from 500 to 100,000 gallons per day.

The real concern to everyone is that the worldwide need for more water is so urgent that saline sources must be converted in volumes of millions of gallons per day. Immediate action to bring this about must be taken and the next logical step is the building and testing of large plants.

The full potentials, both in cost of construction and cost of operation, will never be realized from the electrodialysis or any other system until truly large plants are built.

It is self-evident that great economies will accrue in the large-volume production of membranes and associated equipment. Ionics can prove from extensive manufacturing and detailed engineering experience that in a several-million-gallon-per-day plant the capital cost can be reduced by a factor of at least 2, and operating costs by a similar factor.

The problem is that no municipality, industry, or agricultural district in the United States has been willing to spend $1 million to $2 million to demonstrate such a radically new process on a sufficiently large scale, even in the face of an ever-growing threat of a shortage of water.

It seems clear to us that the intent of the Saline Water Act of 1952 has for certain processes been accomplished. These processes are 2 or 3 variations of distillation techniques for sea water and electrodialysis for brackish water. These are ready to prove out in production-size demonstration plants. These plants should be built by the Department to ascertain the real engineering and economic potentials of the processes in actual field operations.

We feel it would be a mistake for the OSW as presently constituted to have to distract itself from its statutory responsibility for research and development from the new idea to the pilot plant by having also to build and operate production-type demonstration plants. Therefore, we believe that a demonstration program would best be carried out under the Secretary of the Interior, in close liaison with OSW, but under separate responsibility.

We sincerely believe that after such a demonstration the first real dividends of the Saline Water Act of 1952 will be realized. It is a truism in research circles that a process never satisfies the researcher, and unless management makes a decision to freeze designs and sets a

date for production, plant contruction, and operation, the process is forever and a day getting out of the research laboratory. This does not mean that research ceases in water desalting any more than it ceased in new aircraft after the first commercial aircraft took to the air.

It further seems self-evident that after the expenditure of so much time and money the Government has every reason to demonstrate the reliability and economics of advanced processes to industry, agriculture, and municipalities, which have always relied so heavily upon the Federal Government for advice, suggestions, and information on public water supplies, systems, which so vitally affect public health. We submit that a small company such as ours does not have the financial resources to build on its own account a demonstration-plant program costing up to $2 million. Ionics has already gone very far by spending $1¾ million of capital and earnings on the development of membranes and equipment.

Another area we would comment upon derives from Ionics' extensive experience on overseas saline-water problems. You probably are aware that more than half of the 24 units Ionics has sold and installed are located in the Middle East and North African areas. In these areas, there are almost unlimited supplies of brackish water available both along the coast and inland. For example, you may be interested in the fact that one of the world's large brackish artesian basins, the Oued R'hir, covering more than 4,500 square miles, is located in Algeria. Think of the industry and population in this oil- and mineral-rich region this one source alone could support if economically converted to potable water.

The point we would make is this: Can there possibly be an instrument of international good will with more psychological impact than to be able to offer a native of these areas 5, 10, or even 50 gallons of good, sweet water every day when he, his father, and his ancestors have had their economy limited by the availability of perhaps no more than a quart of brackish water containing in the order of 7 to 17 times the minimum salt content recommended by the United States Public Health Service?

The United States could have been doing just this 2 or 3 years ago. Instead, the English, the Dutch, and the South Africans are getting the credit with their first electrodialysis plants now under construction.

Ionics has had several small plants operating in some of these areas for over 2 years now, and had already at that time as much or more engineering and operating experience with which to build a large demonstration plant as the Dutch, English, and South Africans have today. We are at a loss to understand why the OSW did not recognize this and, for the sake of United States prestige, take advantage of this United States potential. Instead, we find OSW encouraging and pointing with pride to the foreign scientists and laboratories, while they duplicate the United States work on membrane technology.

We believe that this attitude stems from a lack of full technical appreciation of the extent of United States technology on membrane systems, and we suggest that what OSW needs is more technical personnel with the appropriate qualifications. These additions would permit it to more thoroughly and rapidly evaluate the technical worth of operating reports, proposals, and the research-and-development data received.

We wonder, too, about the degree of urgency assigned to the program. In our travels around the country and abroad we are constantly amazed at the serious concern of municipalities and State governments and by their efforts to forestall a water shortage.

California, for example, is formulating an $11-billion program to bring northern California water down to the southern part of the State. It is currently trying to get an authorization for a billion and a half dollar increment of such a program. Meanwhile, Catalina Island has a water shortage, San Diego is borrowing water from Los Angeles, Ventura County has a shortage, Coalinga gets its drinking water by railroad tank car. In the agricultural areas, farmers are having to drill deeper and deeper for water to irrigate their fields, as the water table falls and as other wells become contaminated by salt water intrusion.

In the Southwest and Great Plains regions, more and more brackish water is being used for irrigation, leaving a slowly increasing amount of minerals on the soil, some of which will one day ruin it for agriculture.

What price water? Who is to say what people would pay for an abundant supply of sweet water? Who is to say that water produced by conversion must cost less than any arbitrary figure chosen today, and that any proposed system which cannot guarantee that figure today is unworthy of development funds?

We believe, and many share this belief, that brackish and sea water conversion in big-scale demonstration plants must be initiated now, not 5 or 6 years from now, and that the most promising processes which are out of the pilot stage must be chosen for these demonstrations.

This saline water program must be bold, dynamic, and imaginative. The atomic bomb was not built in 5 years by indecision or reluctance to try a promising process.

(The subcommittee subsequently received the following communication from the Department of the Interior commenting on Dr. Juda's testimony:)

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
*Washington, D. C., April 30, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee of the Committee on Government Operations, House Office Building, Washington, D. C.*

DEAR MR. JONES: This letter is in reply to yours of April 18, transmitting a copy of the statement given before the Public Works and Resources Subcommittee by Dr. Walter Juda, of Ionics, Inc.

The Department certainly appreciates the opportunity to comment on his statement, and a copy of our remarks entitled "Summary of Cooperation Between Ionics and the Office of Saline Water" is enclosed for such use as the committee may consider appropriate.

In response to Mr Romney's telephone request on April 23, there are enclosed two copies each of the contracts negotiated with Ionics, Inc., and a copy of the cooperative agreement with the State of California. [1]

Sincerely yours,

FRED G. AANDAHL,
*Assistant Secretary of the Interior.*

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[1] The cooperative agreement referred to appears as exhibit 9, p. 366. The contracts with Ionics, Inc., are available in the subcommittee files.

SUMMARY OF COOPERATION BETWEEN IONICS, INC., AND THE OFFICE OF SALINE WATER (APRIL 28, 1958)

The statement of April 15 by Ionics, Inc., shows that the company deserves recognition, sympathy, and understanding. Although electrodialysis was used in Europe as early as 1925, Ionics introduced its use for desalting to the United States and pioneered in its development in 1948. The firm of hardworking young men is representative of American small business. Accordingly, it has been given every possible consideration by the Office of Saline Water commensurate with sound Government research contracting practices, and within the limits of the firm's particular process.

From April 1952 to December 1956, the Department sponsored development of the Ionics brackish water conversion process. Three research contracts were awarded. The first Ionics contract was with the Bureau of Reclamation for $10,000. The other two were with the Office of Saline Water for $30,000 and $148,635. The total amount was $188,635. To date, this is the third largest sum expended with any one firm. At the time of the last work in late 1956, it was the largest amount expended on any one desalting process.

In the beginning of the program, Ionics was invited to become a consultant to the saline water program on electrodialysis and membrane work, in order that its experience in membrane development would be available to the Office of Saline Water. The firm declined the invitation. It gave as part of the basis for its decision that it feared that such consulting work in reviewing the membrane proposals of others might jeopardize its patent position. Other highly experienced and eminent membrane specialists were secured as consultants and have served with great competence throughout the program. They have evaluated and passed on the need for the present membrane research of the Office of Saline Water.

In the fall of 1952, following the earlier work with the Bureau of Reclamation and after many meetings with personnel of the then new Office of Saline Water, the company submitted a research proposal for development of its process. Negotiation was exceptionally complex and lengthy because of the company's desire for and insistence on explicit patent protection and nondisclosure of information which it considered confidential. Finally, a contract was signed on January 16, 1953, for $30,000 for a laboratory program and Ionics became the first contractor under the new saline water program. That contract contained a special provision for a confidential final technical report. The work was completed August 16, 1953. A confidential report and a nonconfidential report were submitted. However, all of the results obtained under the contract were ultimately released and made available to the public in research and development report No. 1.

Negotiations for a new contract began in November 1953 while discussions of publication of the results of the first contract were still underway. The Office of Saline Water declined to include another provision for a confidential technical report. This, together with much negotiation of overhead charges and patent protection provisions, required several meetings. A revised proposal was submitted on December 12, 1953. More meetings and discussions were held regarding the proposed field test and the confidential handling of technical results. Finally, a revised proposal for design, construction, and field testing was submitted in January 1954.

There were again delays in reaching agreement on what the firm considered as proprietary information. The Office of Saline Water finally declined to include again a provision for a confidential report but did, with some reluctance, include a provision for protection of what the firm considered as confidential proprietary knowledge that might become known to Office of Saline Water personnel through the contract research work. The contract was signed April 1954 in the initial amount of $83,230. With subsequent amendments for additional work, the total amount was increased to $148,635. The work under the contract was completed in December 1956. The restrictions on Government personnel regarding nondisclosure of Ionics proprietary information were exceedingly difficult to administer, particularly in explaining to the many visitors to the field tests why information was being kept in confidence by Department personnel on work of a public nature.

Each of the two contracts contained patent clauses wherein the Government had rights to inventions resulting from work under the contract. When the company was requested to report on patentable inventions developed under the

contract, it reported in both cases that nothing patentable had been developed under the particular work for the Office of Saline Water.

Following the field test, the unit was moved to the Denver laboratories of the Bureau of Reclamation for membrane durability tests and other experimentation and improvement. Ionics objected to having its product sent to the laboratories. The firm recommended against operation on synthetic water and urged that field testing of the unit at a number of locations be continued. The Office of Saline Water felt that there was nothing to be gained by repeating what had just been done, other than further public demonstration of the Ionics equipment.

The Office of Saline Water and Reclamation scientists and engineers fully understood the problems connected with the use of synthetic water available at the laboratories. In fact, experience of the last year has proven the value of using the membrane durability test as a nucleus for a general program to improve electrodialysis at the Denver Reclamation Laboratories.

Near the close of the last contract work, a general discussion of the status of electrodialysis improvement was held with Ionics on December 11, 1956. The Office of Saline Water encouraged Ionics to submit further research proposals since the office did not feel that as much had been achieved as was desirable. As a result, Ionics presented three suggestions as follows:

(*a*) Electrodialytic boron removal.

(*b*) Design, construction, and test of a high transfer Ionics cell with increased hydraulic rating.

(*c*) Use of supersaturated brine streams for increased water conservation.

These suggestions were considered in a joint conference in Washington on February 13, 1957. The Office of Saline Water took the following position:

(*a*) The boron removal study was not of sufficient potentiality to warrant study at that time.

(*b*) It was felt that other hydraulic electrodialysis systems should be investigated by OSW before awarding another large contract on the Ionics flow design.

(*c*) A study of supersaturated brines was of significance in view of scaling problems, and Ionics was requested to submit a standard proposal for this study. However, no proposal has been received to date (February 13, 1957, to April 27, 1958).

At the invitation of the Office of Saline Water, Ionics, Inc. participated in a meeting of organizations working in membrane development on February 21, 1957. This meeting was for the purpose of obtaining the cooperation of the commercial organizations in membrane evaluation as a guide to the saline water conversion program. Although Ionics, Inc., by letter dated February 26, 1957, submitted some information on its methods for determining membrane properties, the firm stated that it had designed a cell which would be ideal for testing different types of membranes, but could not make the system available to the saline water conversion program. The letter also stated that Ionics had developed a new technique for measuring the maximum power input, but again the company could not make this available to the saline water program.

The letter of February 26 also stated that Ionics was prepared to conduct in its own laboratories the tests which the Office of Saline Water was planning to conduct at the Denver reclamation laboratories. The Office of Saline Water felt that evaluation of membranes produced by commercial firms in the laboratory of a competitor was not advisable. A Government laboratory was felt to be in a better position to work with commercial organizations. The circumstance that Ionics had both a procedure and a test unit useful in the program being planned by the Office of Saline Water, but which they were unwilling to make available to the Government program, was most discouraging.

From January 1957, to April 11, 1958, no proposals in line with the Office of Saline Water suggestions or any other proposals for research and development work have been received from Ionics, Inc. On April 11, 1958, a letter was received from the firm advising that it would like to submit two research and development proposals, totaling $120,000. It has been invited to do so.

Of possible significance are the following facts. At the time the Netherlands cooperative project was first considered in January 1955, the Office of Saline Water canvassed representatives of all those known to be engaged in this field at that time in the United States, asking their advice whether they felt the Federal Government should cooperate in the Dutch research. Six firms or specialists were contacted, including Ionics. Only Ionics, Inc., opposed the participation.

In June 1955, Ionics, Inc., was refinanced by a substantial security sale and was marketing its fully developed equipment. It was and is now, as far as is known, the only firm in the United States marketing this type of equipment, although one large chemical firm has recently developed high quality membranes at reduced prices.

The Office of Saline Water program of membrane work has been rigorously evaluated by competent scientists and is believed to be in accord with the status of the art at the various times work was undertaken. Since Ionics, Inc., had no further research to suggest other than rather minor improvements to that 1 developed process, and has not submitted an application to conduct the 1 research recommended by the Office, no further work has been carried out with the company since December 1956. Ionics, Inc., has contributed to the field of electrodialysis and has a good technical staff. The Office of Saline Water would be pleased to consider further cooperation with the firm on any essential research and development, on any basis which would assure that all of the final results would be readily available for general public use.

Mr. JONES. Thank you very much, Mr. Juda.

Mr. Fascell, any questions?

Mr. FASCELL. I don't have any questions, Mr. Chairman, except that the statement certainly lays on the record some questions that need to be answered, in my opinion. I haven't heard all of the testimony but I'd certainly be interested in listening to the other side of this discussion, because I think they are very appropriate and very pertinent. I raised the question here, I believe, the first time I got a chance to come into this meeting, on the theory of cost on this whole process. I still am at a loss to understand thoroughly why you have to predetermine cost. It would seem to me that demand would be the great factor on this. I find it very difficult to challenge the logic of the last statement that the doctor has made with respect to delineating processes because of initial cost, if it is a research program.

Mr. JONES. Well, the question as to cost is one that would be in doubt if we took testimony here for the next year, because the experts themselves——

Mr. FASCELL. I can understand that, how you can have all kinds of discussions and arguments on cost, because you have to first decide what cost is.

Mr. JONES. Well, Doctor, with a 10-year program with a million dollars a year, we are not going to have too much development work, because you can't carry on a program of research and development at the same time when you don't have a breakthrough on it. So, unless the Congress or unless public opinion is behind a more enormous program than we've got at the present time, I don't think with a million dollars a year you are going to do very much, especially when you are only spending $25,000 a year on research right now.

Mr. Brownson, do you have a question?

Mr. BROWNSON. Doctor, has your organization been constantly in contact with the Office of Saline Water in an attempt to sell your services and your program?

Dr. JUDA. Attempting to.

Mr. BROWNSON. And I take it that up to date you haven't had too much acceptance.

Dr. JUDA. We have sold a trailer-mounted membrane unit some years back, and we have made suggestions and proposals on basic improvements.

Mr. BROWNSON. Their trailer unit is now pretty obsolete?

Dr. JUDA. It is now in Denver. It's operating, but we have made many changes since that time.

Mr. BROWNSON. So your whole program could not be fairly judged on the basis of that demonstration trailer unit you developed some years ago.

Dr. JUDA. Certainly not in a complete way.

Mr. BROWNSON. You made a suggestion in your testimony, which appears on page 8 of your printed version, when you said that the Office of Saline Water needs more technical personnel with appropriate qualifications. Would you care to elaborate on that a little bit? That is a constructive criticism that I think we'd like to have in a little more detail.

Dr. JUDA. One experience is that any one of these technologies, when they become close to the practical stage, require more and more detailed knowledge of which specific improvement can really produce the best economic results. And it is very difficult for an office which has that many different technologies to handle, to have everyone really understand the implications of the proposal. As a result, most of our talks have been limited to general contractual matters and have not been limited directly to the merits of the particular proposal or thought expressed. And I for one believe very strongly that this should come as No. 1, the technical merit of any idea, be it ours or anybody else's; should be closely examined before any real sponsorship is undertaken. And this is where I think more technical people with the right qualifications could help the Office enormously.

Mr. BROWNSON. Do you have any idea of the size of their staff?

Mr. JONES. Let me make an observation right there, Mr. Brownson. Do you realize that the Office of Saline Water has had a vacancy open down there for a long period of time? They are trying to get hold of these people. They cannot employ them because they cannot find the experienced personnel. And that is one of the problems that they are dealing with now, trying to find trained personnel to fill those vacancies.

Mr. BROWNSON. On the basis of your observations, how much of an expansion in this field of technical personnel would you think would be justified at this stage of their program?

Dr. JUDA. I have the feeling that, if you would find one really very well-known man with an international reputation, whom you would get down there, perhaps two, on a full-time basis, on a leave of absence from some institution, that you could help it quite significantly.

Mr. BROWNSON. What is the latest unit that you have delivered and which is now in operation?

Dr. JUDA. The latest unit went out about, I would say, just a few weeks ago. It is to the French military, and it is going to go into the heart of Algeria.

Mr. BROWNSON. On the basis of your recent experience, what is your latest cost per gallon?

Dr. JUDA. On what scale? I would say this. As we testified at the Senate a few weeks ago, on the basis of a million gallons per day order of magnitude plant, we would accept orders, on the technology as we have it today, in the order of 65 cents a thousand gallons. With the improvements we are working on alone, we think we can bring it down to the order of 35 cents per thousand gallons.

Mr. BROWNSON. How large is the unit you delivered to the French?

Dr. JUDA. On the order of about 50,000 gallons a day, or more.

Mr. BROWNSON. Thank you very much, Mr. Chairman. That's all I have.

Mr. JONES. Dr. Juda, I have in my hand a report made by the Office of Saline Water, Progress Report No. 11, which was issued jointly by the Department of the Interior and by Ionics, Inc. And on page 2 of that report is the following quotation: "The value of pilot size field testing of new processes was shown by the results of the field test."

Now, listen to this: "Cost estimates based on the field results were about six times higher than previous estimates based only on laboratory results."

Now, who made the miscalculation?

Dr. JUDA. Could I elaborate on that?

Mr. JONES. Yes, sir, that's what I am asking you to do.

Dr. JUDA. This statement I think was made by the Office of Saline Water. And if I made an analogy, I might say this: Take the algae process today which was discussed. Literature researches have been made——

Mr. JONES. First, let me identify the language here. Is this part of your language? Did you concur in it?

Dr. JUDA. No, this is not part of our language. This statement on the face of it is correct, but the interpretation of it is very misleading, because the original estimates——

Mr. JONES. Is this an interpretation or is this a statement of fact?

Dr. JUDA. The statement of fact is——

Mr. JONES. You read it.

Dr. JUDA. I have seen this, of course.

Mr. JONES. Well, do you take exception to it?

Dr. JUDA. I do not take exception to the statement as it stands. I do take exception to the lack of explanation of why this was so and why this has been so in every other process ever calculated, this type of thing. Let me give an example.

Mr. JONES. Is it the policy of the Department——

Dr. JUDA. No, I think I can illustrate it by a very simple example. When we made our laboratory evaluations, we looked 10 or 20 years ahead. For example, we used the membrane life of 10 years in that calculation. When we make a field operation of a pilot unit, we don't know whether the membranes will last 10 years or not. We have perhaps 2 years of experience. So when we go out and sell this equipment as a commercial company, we cannot guarantee 10-year life on the basis of 2 years' operation. So, therefore, your membrane cost which we have to charge today to the process is five times what the anticipated value is after you test it for a period of 10 years.

Mr. JONES. In other words, the subsequent events have disproven that?

Dr. JUDA. No; we do not know yet whether the membrane will last for 10 years, but we cannot wait for 10 years until we sell the first piece of equipment. Do you follow that?

Mr. JONES. Yes, I understand. What you are saying now is that our assumption is going to be different from this even though this is a fact at the present time.

Dr. JUDA. Right. You use different assumptions at different stages of development. That's what I'm trying to say.

Now, for example, this morning Mr. Levin said that electrodialysis uses 150-watt-hours for 10 gallons of sea water. We have operated on 10 kilowatt-hours but we can't use that number today because the plant would be so huge that nobody would buy it. So when you come to the commercial stage of delivering equipment, you use an entirely different set of assumptions than when you look at the laboratory investigations.

Mr. JONES. Mr. Indritz, any questions?

Mr. INDRITZ. No, sir.

Mr. JONES. All right, sir, thank you very much.

That is the last witness and that concludes the hearing.

(Whereupon, at 11:27 a. m., the subcommittee adjourned.)

(For communications received by the subcommittee and made part of the record, see appendixes A, B, and C.)

# APPENDIXES

## Appendix A—Letters From the Subcommittee on Public Works and Resources to Federal Agencies, and Responses Thereto

### Item 1

February 4, 1958.

Hon. John Foster Dulles,
*Secretary of State,*
*Washington, D. C.*

Dear Mr. Secretary: Under the duty imposed on the Committee on Government Operations to study the operation of governmental activities at all levels to determine its economy and efficiency, this subcommittee is inquiring into the Federal Government's efforts to produce, from sea water, water suitable for agricultural, industrial, and other beneficial consumptive uses. The Office of Saline Water of the Department of the Interior now is engaged in such effort under the act of July 3, 1952 (66 Stat. 328, ch. 568) as amended by the act of June 29, 1955 (69 Stat. 1958, ch. 227; 42 U. S. C. sec. 1951, et seq.).

On March 16, 1950, the President of the United States addressed a letter to your predecessor in office and to the heads of several other agencies requesting cooperation with the Secretary of the Interior in the collection of available information and future collaboration in the further analysis of such data. Enclosed are copies of two letters by the President dated March 16, 1950, detailing his request.

It would be appreciated if you would supply to us a detailed statement of the extent to which your agency has acted since March 16, 1950, with respect to work on the conversion of sea water.

Sincerely yours,

Robert E. Jones, M. C.,
*Chairman, Public Works and Resources Subcommittee.*

(Identical letters were written to heads of six other agencies.)

Department of State,
*Washington, February 20, 1958.*

Hon. Robert E. Jones,
*Chairman, Public Works and Resources Subcommittee, Committee on Government Operations, House of Representatives.*

Dear Mr. Jones: Reference is made to your letter of February 4, 1958, to the Secretary, which was acknowledged by telephone on February 10, in which you asked for a statement of the extent to which the Department "has acted since March 16, 1950, with respect to the conversion of sea water."

The Department of State has been very much interested in this matter because of its potential importance to many countries in the free world. Our activities to date have been largely facilitative in nature. They fall into three general categories: (1) continuing liaison with the Department of the Interior; (2) directing research funds through UNESCO; and (3) sponsoring legislation for a specific project.

(1) *Liaison.*—In 1950 the Department established the post of liaison officer to collaborate with appropriate officers of the Department of the Interior. Initially the Department officer assisted in formulating suitable legislation establishing the saline water conversion program of the Department of the Interior. Later, he facilitated the cooperation with that program of other governments and international bodies concerned with desalinization research. He is responsible

for assuring that the overseas relations of the program are consistent with the foreign policy objectives of the United States.

(2) *UNESCO funds.*—The Department has facilitated the program periodically by reviewing UNESCO budgets and approving allotments of funds to projects helpful to the program whenever it believed such course justified. Recently, for example, the Department concurred in the UNESCO establishment of a center in Paris for the exchange of information, including information on desalination, between governments and other international organizations, such as the OEEC. It also concurred in another UNESCO proposal calling for a symposium on salinity problems to be held in Teheran, Iran, in the autumn this year.

(3) *Legislation.*—In August 1957, the Department sponsored a bill helpful to the program, and obtained from Congress an appropriation of 200,000 Israeli pounds to be used "to finance a program of scientific research and development in the field of desalting of sea water." The terms of the legislation stipulated that the project was to be "related to the desalination research coordinated by the United States Department of the Interior." One research project proposal has recently been submitted by the Research Council of Israel, but has not yet been approved, so no funds have actually been expended as yet.

If I can be of any further asssitance in supplying information which your subcommittee may require, please do not hesitate to call on me.

Sincerely yours,

WILLIAM B. MACOMBER, Jr.,
*Assistant Secretary.*

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DEPARTMENT OF STATE,
*Washington, March 14, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*Committee on Government Operations,*
*House of Representatives.*

DEAR MR. JONES: In response to Mr. Phineas Indritz' request to Mr. Thomas Robinson of the Department for additional data concerning the desalting of sea water research project in Israel we submit the following information:

The United States Information and Educational Exchange Act of 1948, as amended (sec. 1011 of Public Law 402, 80th Cong., as amended), authorizes the Government of the United States to guarantee convertibility into United States dollars of foreign currencies received by American enterprises which produce or distribute abroad informational media consistent with United States interest. Such a program is being conducted in Israel pursuant to an agreement entered into between the respective Governments of the United States and Israel effective June 9, 1952.

The Government of Israel and the Government of the United States agreed, effective June 9, 1952, that funds generated by this informational media guaranty program would be used in Israel for cultural, scientific, and educational purposes, among others. In 1957, pursuant to this authority, the Congress of the United States appropriated certain funds to purchase Israeli pounds generated by the above-cited IMG program (Public Law 85–170, 85th Cong.). It was the sense of the Congress that the Israeli pounds so purchased be used in Israel for certain cultural, scientific, and educational projects. (See p. 232, supplemental appropriation bill of 1958, hearings before the subcommittees of the Committee on Appropriations, House of Representatives, 85th Cong., 1st sess.)

There were 42 specific projects presented to Congress during the hearings on the supplemental appropriations bill for fiscal year 1958 (Public Law 85–170, 85th Cong.). Among those 42 projects was one providing for a grant to Israeli research institutions for conducting research in the desalting of sea water. The project, as described before both Senate and House appropriation committees (p. 244, supplemental appropriation bill of 1958, hearings before the subcommittees of the Committee on Appropriations, House of Representatives, 85th Cong., 1st sess.) was as follows:

"Water-desalting research ---------- $111,111

"To finance a program of scientific research and development in the demineralization of brackish and sea water.

"This project is to be carried out through a grant administered by the Weizmann Institute and would be related to the desalination research of the United

States Department of the Interior. The results of this study should be of value to both the United States and Israel."

Our Embassy at Tel Aviv has forwarded to us a brief outline of a desalting research project which the Israelis propose undertaking. This project, as outlined, is concerned with the electrodialysis process for desalting brackish waters in arid areas of Israel. In line with a previous understanding we had with the Office of Saline Water, Department of the Interior, we sent this outline over to that Office for its advice and comments. The grant-in-aid for the project has not yet been made by our Embassy; after we receive the Department of the Interior's comments as to the merits of the proposed project, we will advise our Embassy accordingly.

If you have any further questions with respect to this project, please do not hesitate to ask them.

Sincerely yours,

WILLIAM B. MACOMBER, Jr.,
*Assistant Secretary.*

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FEDERAL POWER COMMISSION,
*Washington, February 13, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee, Committee on Government Operations, House of Representatives, Washington, D. C.*

DEAR MR. CHAIRMAN: This refers to your letter of February 4, 1958, requesting the Commission to supply you with a detailed statement of the extent to which it has acted since receipt of the letter from the President, dated March 16, 1950, with respect to work on the conversion of sea water.

A summary of the Commission's actions regarding this matter follows:

(1) In a letter dated March 21, 1950, responding to the President, the Commission stated that it would be very glad to cooperate with and assist the Secretary of the Interior in any way it could with respect to research and development work for the production from sea water of water suitable for agricultural, industrial, and other beneficial consumptive uses.

(2) By letter of April 12, 1950, responding to a letter from the Secretary of the Interior, the Commission designated a representative with whom the Secretary's representative could make contact for such assistance as might be available from the Commission. The Secretary was assured that the Commission would be glad to cooperate in this important matter.

(3) On April 21, 1950, representatives of the Commission attended an interagency conference on the salt-water-conversion program, at which approximately 30 persons from the several interested Federal agencies were in attendance.

(4) On May 5, 1950, the Commission furnished the Bureau of the Budget, at its request, with a report on S. 1300, 81st Congress, a bill relating to research and development of practical means of providing for salt water conversion. The report stated that the Commission considered the proposal to be extremely important and urged that the research be undertaken at the earliest possible time.

(5) On March 9, 1951, a Commission representative attended an interagency meeting at the Department of the Interior on the problems of salt-water conversion and artificial precipitation at which the bills S. 5, H. R. 6, and H. R. 7, 82d Congress, were discussed. No testimony before congressional committees on these bills was expected of Commission representatives, since the matter of power was not directly involved.

(6) No further action on this matter has been taken by the Commission and none has been requested since authorization of the present program by the act of July 3, 1952, as amended by the act of June 29, 1955.

It is hoped that the foregoing will provide the information you have requested.

Sincerely yours,

JEROME K. KUYKENDALL,
*Chairman.*

DEPARTMENT OF AGRICULTURE,
*Washington, D. C., February 13, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*Committee on Government Operations, House of Representatives.*

DEAR CONGRESSMAN JONES: We are pleased to acknowledge your inquiry of February 4 concerning the participation of the Department of Agriculture in the Federal Government's efforts to convert sea water into water suitable for agricultural and industrial uses.

The Department of the Interior has been authorized to proceed with research on the desalinization of sea water, but no funds for such studies have been available to the Department of Agriculture. Consequently, this Department has taken no action with respect to work on the conversion of sea water.

Agriculture is conducting research on the characterization, diagnosis, and management of saline and alkali soils. Obviously, the salinity of the irrigation water is a major consideration in the salinization of soils. The United States Salinity Laboratory of the Agricultural Research Service has developed and compiled an appreciable body of information on the diagnosis and improvement of saline and alkali soils. This is embodied in Agriculture Handbook No. 60, and a copy of this book is submitted herewith. Copies of this book have been made available to interested parties in the Department of the Interior.

If we can be of further assistance, please do not hesitate to call upon us.

Sincerely yours,

E. L. PETERSON,
*Assistant Secretary.*

(Book placed in subcommittee files.)

ASSISTANT SECRETARY OF DEFENSE,
*Washington, D. C., February 24, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee, Committee on Government Operations, House of Representatives.*

DEAR MR. CHAIRMAN: Secretary McElroy has asked me to reply to your letter, dated February 4, 1958, requesting a detailed statement of the extent to which this Department has acted since March 16, 1950, with respect to work on the conversion of sea water.

In compliance with President Truman's March 16, 1950 letter, this Department through a designated representative on the staff of the Research and Development Board compiled a detailed report of completed and active research and development work on saline water conversion in the various segments of the Department of Defense. The Department of Defense representative's first formal participation in this activity was on April 21, 1950, when he reviewed defense activities on saline water conversion at a joint conference called by the Department of Interior and attended by representatives of all interested Government agencies.

From the date of this first conference until the approval of Public Law 448 on July 3, 1952, this Department assisted the Department of the Interior by (1) developing information on both military and industrial requirements for water, (2) providing a statement of Defense Department interests in the proposed program, and (3) providing detailed information on Defense Department activity in saline water conversion.

Immediately after the enactment of Public Law 448 formal liaison was established between the two departments in accordance with provisions of the law. Subsequent to that time, Defense and Interior Department personnel have held numerous joint conferences for the purpose of developing and conducting a coordinated program. Working level scientists and engineers from the three military departments have participated in several of these joint conferences, including field trips, which have been effective in the planning and pursuit of a program of common interest.

In addition to these conferences which have been held approximately twice each year, close coordination has been maintained through the medium of correspondence, telephone calls, and personal contacts. There also has been a free interchange of technical progress and final reports on projects underway by each department.

The annual reports published by the Office of Saline Water, United States Department of the Interior, contain charts showing all projects in the saline water program. These charts include all Defense Department projects pertinent to the program.

A résumé of the Research and Engineering work on water desalting in the military departments is attached to provide you with additional information on the defense program.

You will note that the objectives of the military program (i. e. to provide boiler water for ships and potable water for troops in the field and at remote installations) is quite different from the objective of the Department of the Interior program. Although the objectives are different, mutual benefit has been derived by both departments from the close coordination of the programs.

It is a pleasure to provide the above résumé of our joint activity with the Department of the Interior.

Sincerely yours,

PAUL D. FOOTE.

RÉSUMÉ OF DEPARTMENT OF DEFENSE WATER DEMINERALIZATION PROGRAM, FEBRUARY 21, 1958

Following is a brief résumé of work done by the military departments on the desalting of water:

ARMY

The Army Corps of Engineers (1) designed and developed a 1,250-gallon-per-hour semipermanent thermocompression distillation unit. This unit was tested at Kindley Air Force Base, Bermuda. As a result of this work, specifications were prepared and four 2,000-gallon-per-hour units were built. These units are now producing potable water at Kindley Air Force Base. Fuel to distillate ratio is approximately 1 to 300 with periodic acid descaling. (2) Designed and developed a 125-gallon-per-hour portable aluminum and aluminum alloy thermocompression distillation unit. The object was to eliminate use of critical materials, reduce weight, reduce cost, and simplify. The experimental unit proved satisfactory except for troubles with dissimilar metals. This unit has been redesigned eliminating copper bearing metals in contact with water. A full-scale test of the redesigned unit will be made in the near future.

In addition to the above projects, the Army has a general water research project under which it is (1) exploring ion exchange resins; (2) determining limitations of the electrodialysis method; (3) exploring promising new techniques; and (4) following industrial developments and the saline water conversion projects being sponsored by the Office of Saline Water of the Department of the Interior.

NAVY

The Bureau of Ships has a continuing program to develop more efficient and reliable equipment and methods for demineralizing sea water for shipboard and submarine uses such as boiler water makeup, heating system, decontamination, submarine batteries, and drinking water. The program involves new design distillation equipments, including multiple stage flash type, vertical basket type, fluted tube type, thermocompression type and an abandon ship still. The effort includes research on corrosion and materials, development of new designs, design and development of components, reduction in the use of critical materials, and the evaluation of commercial equipment. Most evaluation work is done by the Bureau's laboratories. Developmental and construction work is done largely through contract with industry. Following is a partial list of contractors who are now or have recently participated in this program: Maxim Silencer Co.; Badger Manufacturing Co.; Griscom-Russell Co.; Cleaver-Brooks Co.; Arthur A. Crafts Co.; Read-Standard Co.; Young Radiator Co.; and Bethlehem Steel Co.

The Bureau of Ships is also evaluating a small electromembrane dimineralizer for possible submarine use. This unit was developed by Ionics, Inc.

The Bureaus of Yards and Docks effort is directed largely to improving the efficiency and reliability of thermocompression distillation equipment for use at shore establishments. This effort has resulted in the development of a number of reliable units in the range of 85 gallons per hour to 200 gallons per hour by several manufacturers. Scaling is still a problem in all sea water distillation equipment. Bureau of Yards and Docks is working along with in-

dustry, the other military agencies, and the Department of the Interior on this problem. Under contract with Battelle Memorial Institute it has studied optimum design of components for a thermocompression still. Results of this study are being incorporated into a distillation unit of optimum design. This Bureau is also evaluating two electromembrane demineralizer units—one on sea water and the other on brackish water.

AIR FORCE

The Air Force has no research and development programs on water but depends on the Army engineers for development work in water demineralization equipment. It has, however, a number of new design or experimental water demineralizer units under test for specific application. These include thermocompression distillation plants at Kindley Air Force Base, Bermuda; an Ionics, Inc., electromembrane unit on a Texas tower warning station; and an Ionics unit at P–25 Havre, Mont.

All three military departments are following the Department of the Interior water demineralization program closely for developments with possible military application. One development which promises to have military application is a rotary-type thermocompression distillation unit known as the Badger-Hickman still.

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HOUSING AND HOME FINANCE AGENCY,
*Washington, D. C., February 24, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee of the Committee on Government Operations, House Office Building, Washington, D. C.*

DEAR MR. CHAIRMAN: Your letter of February 4, 1958, addressed to the Administrator of General Services Administration, has been forwarded to this Agency for reply. The experimental work described in the following was a Federal Works Agency activity under Public Law 510 of the 78th Congress, FWA at that time being composed of Public Roads Administration, Public Buildings Administration, and the Public Works Administration. The FWA was dissolved June 30, 1949, and the constituent that had been PWA was absorbed by the then created General Services Administration. The same segment, known as Community Facilities Service, later transferred to the Housing and Home Finance Agency, is now one of the constituents and known as the Community Facilities Administration. The foregoing will explain why the key people in this experiment, relating to the solar distillation of sea water, are now a constituent of HHFA.

Under Public Law 510, which included a rather extensive public works program for the Virgin Islands, it was necessary to investigate all possible sources of potable water, particularly for the island of St. Thomas. There are no streams and due to the character of the terrain, underground sources such as wells of any capacity were impossible to find. The two elements most plentiful were sea water and solar energy, and to determine the feasibility of utilizing these elements, a pilot plant was set up, first on the island of St. John and later moved to the outskirts of Charlotte Amalie on the island of St. Thomas. This move was made because of difficulties in servicing the unit installed on St. John during rough weather. The passage from Red Hook on St. Thomas to Cruz Bay on St. John was periodically interrupted by storms and heavy seas, forcing the move to insure continuous observation. The pilot plant was operated for about 6 months under careful supervision in 1948–49. At the same time other possible sources of fresh water were under investigation.

The traditional method of obtaining fresh water had, for generations, been the catchment method from roofs and paved areas on the mountainsides. The only public water supply in Charlotte Amalie was through a salt water distribution system, used essentially for fire protection and sanitary servicing. The fresh water supply was fantastically low, and this was a severe deterrent to any development, either industrial or commercial which, of course, was necessary if the islands were to become even partly self-supporting.

The end result of the experiment might be summarized by the statement that if there were no other source of water, solar distillation is feasible. Reasoning must go further than that, however, and account must be taken of the maintenance of the necessary plant or equipment and the fact that such installations were at that time most eagerly sought in the more primitive areas of the

world, where even most elemental tools and devices were completely unfamiliar. The experiment proved that a solar distiller, even a simple type such as this pilot plant, would require management, maintenance, and trained attention.

The activities under Public Law 510 were transferred to the Division of Territories and Insular Possessions of the Department of the Interior. This transfer included all records excepting the records of the experimental work in solar distillation. These were retained for adjustment and clarification before transfer. Before this was completed, the saline water conversion program in the Department of the Interior had been authorized, and that authority working cooperatively with the Engineering Branch of the CFA eventually provided much of the information used by Dr. George Lof, the head of a research project authorized under the saline water conversion program and finalized by the published Research and Development Report No. 5, dated February 1955.

As before stated, there is no doubt that solar distillation of sea water is one means of providing a potable water. The outcome, however, of the potable water project for Charlotte Amalie was not solar distillation. It was found that the Burne Field area, the airport for Charlotte Amalie, had the highest rainfall record on the island. When it was necessary to expand the main runway for heavier aircraft, it was so constructed as to provide about 20 acres of rainwater catchment which water was transported to a pumping and treatment plant by large pipes and thence distributed to the city. All available storage facilities were used, and by various adjustments in design it was possible to develop a public fresh water supply which could be controlled from a purity standpoint, a situation that was impossible when the water supply was from hundreds of small, isolated and, in many cases, contaminated cisterns or reservoirs.

There were many inquiries from all parts of the world as a result of the moderate publicity that was attached to this experiment, and it appeared that a source of revenue could be generated by creating on St. Thoms a sort of central point for the production and distribution of distillation units, an industry to which the native craftsmen could be easily adapted and suitable materials were obtainable locally. This was not pursued to any great extent due to the multiplicity of factors and factions that were not in the mood to cooperate at that time.

You will note that this experiment was active in 1948 and 1949, some time prior to the directive from the President. Appreciating your interest, this rather long letter is intended to provide you with background information not previously circulated. The experiment was conducted with all of the simplicity possible to insure complete understanding by the people who would have to live with and operate such an installation to obtain potable water. The fact that the process was not used has no bearing upon its effectiveness elsewhere.

Sincerely yours,

ALBERT M. COLE, *Administrator.*

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THE SECRETARY OF COMMERCE,
*Washington, D. C., April 7, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee, Committee on Government Operations, House of Representatives, Washington, D. C.*

DEAR MR. CHAIRMAN: This is in reply to your request of February 4, 1958, for a statement of the extent to which this Department has acted since March 16, 1950, with respect to work on the conversion of sea water.

The National Bureau of Standards of this Department has been directly interested in this program. A statement with respect to their participation in the saline water program is attached.

The Weather Bureau is also interested in the saline water project. Climatological publications of the Bureau are available to the Department of Interior and have been furnished regularly. We are unaware, however, of the extent to which the Department of Interior has used this material on working on the saline water conversion problem. The Weather Bureau has received no specific request from the Department of Interior for assistance in the saline water conversion problem.

Sincerely yours,

L. S. ROTHSCHILD,
*Acting Secretary of Commerce.*

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DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS

NBS PARTICIPATION IN THE SALINE WATER PROGRAM

The National Bureau of Standards has participated in the saline water program by providing advisory and consultative services to other participants in the program, carrying out related research activities as a part of its basic program, and undertaking a specific research project for the Office of Saline Water, Department of the Interior. Except for the specific participation mentioned in the next paragraph, activities carried on as part of the NBS program has consisted of advisory and consultative discussions by members of the NBS staff with persons concerned with the various phases of the saline water program. These consultations have occasionally led to the issuance of formal advisory opinions. In addition, a brief general survey of saline water recovery was prepared in order to give adequate replies to frequent requests for general information during the period preceding the establishment of the Office of Saline Water.

In 1950, members of the Bureau staff studied and evaluated a process proposed by some French workers in this field. The process involved the recovery of fresh water and the generation of electric power by utilizing the evaporation of water under reduced pressure. Discussion of this process revealed a general lack of appreciation of the rate at which water will evaporate at relatively low temperatures when the residual air pressure in a closed system, is below the vapor pressure of the liquid water. In order to demonstrate the theoretical feasibility of distillation under reduced pressure with low-temperature differences as the driving force, a glass laboratory scale demonstration device was constructed with a small pinwheel turbine driven by the water vapor stream. This device has been maintained and made available for loan as well as being used by members of the Bureau staff and others as a working model in discussions of low temperature-reduced pressure water recovery processes.

In fiscal year 1956, the Office of Saline Water, Department of the Interior, requested the Bureau to undertake a specific research project for the study of ion selective membranes for use in desalting saline water. This project involves basic research directed toward discovering the fundamental physical laws governing membrane processes. The ideal result of this work would be the complete explanation of the details of membrane behaviors in terms of molecular constitution and structure. Information of this nature is of fundamental practical importance in the design of processes for recovery of fresh water by means of electrodialysis and reversed osmosis. The results available at this time include contributions to the art of membrane preparation and improvements in the design and interpretation of laboratory membrane experiments. The emphasis upon a rigorous quantitative treatment of the design and interpretation of membrane experiments will have the practical results of eliminating the need for as much of the preliminary pilot-plant work which is now required in the engineering evaluation of new membranes and processes. The Bureau has continued this program during fiscal years 1957 and 1958.

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THE SECRETARY OF HEALTH, EDUCATION, AND WELFARE,
*Washington, March 10, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*Committee on Government Operations, House of Representatives.*

DEAR MR. CHAIRMAN: This is in reply to your letter of February 4, 1958, requesting information on the extent to which this Department has cooperated with the Secretary of the Interior with respect to work on conversion of sea water. The congressional liaison officer of this Department called your office concerning this correspondence on February 12, 1958.

Following receipt of the President's letter of March 16, 1950, the Public Health Service of this Department appointed a liaison representative to work

directly with the Department of the Interior on the saline water conversion. Specifically our work has included:

1. Consultation by our Public Health Service's Washington technical staff on water needs and water quality requirements.

2. Consultation, as requested, by our research specialists from the Sanitary Engineering Center, Cincinnati, Ohio.

You may be assured that the technical staff of the Public Health Service will continue to assist the Department of the Interior in every way they can with this program.

Sincerely yours,

M. B. FOLSOM, *Secretary.*

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ITEM 2

MARCH 14, 1958.

Hon. LEO A. HOEGH,
*Administrator, Federal Civil Defense Administration, Washington, D. C.*

DEAR MR. HOEGH: In accordance with the prescribed duty of the Committee on Government Operations, House of Representatives, to study the operation of Government activities at all levels with a view to determining its economy and efficiency, this subcommittee is inquiring into the Government's efforts to produce from sea or brackish water, suitable water for potable, agricultural, industrial, and other beneficial consumptive uses.

The Department of the Interior, through the Office of Saline Water, is now engaged in such an effort pursuant to the acts of July 3, 1952, and June 29, 1955 (42 U. S. C., sec. 1951, et seq.). The latter statute specifically provides that the Secretary of the Interior shall cooperate fully with the Federal Civil Defense Administration, in the interest of achieving the objectives of the saline-water program.

I would greatly appreciate it if you could have furnished to us a detailed statement of the activities of your agency with respect to the saline-water program.

It would be especially helpful to us if you could send your response by March 24, 1958.

Sincerely yours,

ROBERT E. JONES,
*Member of Congress, Chairman, Public Works and Resources Subcommittee.*

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FEDERAL CIVIL DEFENSE ADMINISTRATION,
NATIONAL HEADQUARTERS,
*Battle Creek, Mich., March 27, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee, House of Representatives, Washington, D. C.*

DEAR MR. CHAIRMAN: This is in reply to your letter of March 14, 1958, regarding the activities of this agency with the Office of Saline Water, Department of the Interior, in the saline water conversion program.

The Office of Saline Water has been extending full cooperation to this agency in the area of mutual interest. In a national disaster, safe potable water supplies will be vital for the survival of the population. The Office of Saline Water has been engaged in research work on the development of small, low-cost, mobile demineralization units for use in emergencies. Progress made to date, particularly in the fields of distillation and membrane processes, shows some promise of results for practical use for this purpose.

Progress reports by the Office of Saline Water are reviewed as they are furnished to us.

Sincerely,

LEO A. HOEGH.

ITEM 3

FEBRUARY 13, 1958.

Hon. JOHN FOSTER DULLES,
*Secretary of State, Washington, D. C.*

MY DEAR MR. SECRETARY: The Public Works and Resources Subcommittee of the Committee on Government Operations, House of Representatives, is making a preliminary study of the Government's saline water conversion program, administered by the Department of the Interior.

As part of this study, we are gathering information on saline water conversion work being done abroad. With respect to the Soviet Union, however, we have been able to find little information, particularly of a current nature.

It would be greatly appreciated, therefore, if your Department would attempt to ascertain for the subcommittee, through the usual diplomatic channels, any information regarding studies, processes, and programs dealing with saline-water conversion within the U. S. S. R.

If possible, it would be desirable to have such specific data as:

(1) type of process.
(2) quantity of water converted per day (in standard units of measure).
(3) source and salinity of water before and after treatment.

It would be most helpful to the subcommittee if such information as may be quickly obtainable could be forwarded to us March 1, 1958, or as soon thereafter as possible. A more nearly complete reply could then follow at a later date.

Sincerely yours,

ROBERT E. JONES,
*Member of Congress, Chairman, Public Works and Resources Subcommittee.*

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DEPARTMENT OF STATE,
*Washington, March 6, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*Committee on Government Operations, House of Representatives.*

DEAR MR. JONES: I have for reply your letter of February 13 to the Secretary. You requested information concerning Soviet work on saline water conversion.

The enclosed memorandum contains the published information available to the Department on the subject. The Department has also requested the Soviet Embassy to provide the information you desire.

After obtaining the approval of your office, the Department stated in its note to the Soviet Embassy that the subcommittee would be willing to furnish the Soviet Union with a copy of the published results of its study, if the Soviet Union found it possible to supply the requested information.

I hope that the enclosed information will be of use to the subcommittee. The Department will forward to you promptly any further information which is received from the Soviet Embassy.

Sincerely yours,

WILLIAM B. MACOMBER, JR.,
*Assistant Secretary.*

U. S. S. R. METHODS FOR THE TREATMENT OF SEA WATER AND SALINE WATERS

The desalting of natural waters by means of ion-exchange agents is regarded as feasible and expedient in the U. S. S. R. when the total content of sulfate, chloride, and nitrate ions in the water does not exceed 3–4 milligram-equivalents per liter. For instance, procedures have been described for the treatment with sulfonated coal, the cation exchange resin KU–2, and the anion-exchange resins AN–2F and EDE IOP of feed water for uniflow boilers operating at any pressure.[1] As far as the desalting of sea water is concerned, electrodialysis with the use of ion-exchange resin diaphragms or membranes is regarded as the cheapest method and has been found efficient on the basis of the experimental work that has been done (cf T. Sherwood, the Technology Review, No. 11, 1954).

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[1] Principal Schemes of the Chemical Demineralization ("Desalting") of Water and the Regimes of Their Application, by F. G. Prokhorov, Cand. Tech. Sci., Ministry of Electric Power Plans, U. S. S. R., Teploenergetika, vol. 4, No. 10, October 1957, pp. 3–9.

Incidentally, this method is also recommended for the elimination of products of radioactive decay from water (specifically sea water).[2]

The purification (desalting) of sea water and other types of water by electrodialysis with the use of ion-exchange diaphragms has been investigated in detail in experimental work done at the All-Union Scientific Research Institute of Water Supply, Sewerage, Hydraulic Structures, and Engineering Hydrogeology (VODGEO). In the work described, Moscow River water, Lake Balkhash water, Caspian Sea water, and a solution of sodium chloride were treated by means of an electrodialysis procedure. Chambers equipped with resilient diaphragms made of synthetic rubber or plastic (polyvinylchloride) containing up to 80–90 percent of ion-exchange resin (SBS and SDV–3 cation-exchange resins and AN–2F and EDE anion-exchange resins) were employed. Resilient diaphragms were used, because rigid diaphragms in which a solid plastic or a material like cement functions as the matrix deteriorate by reason of the swelling of the ion-exchange resins.

The degree of desalting and/or softening achieved as shown in the following table:

*Degree of desalting of solutions with various original salt contents*

| | Moscow (Moskva) River water | Lake Balkhash water | Caspian Sea water | Solution of sodium chloride |
|---|---|---|---|---|
| Original salt content— | | | | |
| In milligram per liter | 250 | 1,500 | 13,950 | 34,500 |
| In milligram-equivalent per liter | 3.4 | 22.5 | 189 | 590 |
| Total degree of desalting in percent | 93.4 | 88.7 | 81.7 | 88.6 |

By conducting the process in several stages, the degree of desalting can be increased.[3]

Work on the development of the electrodialysis method for the desalination of sea water and saline waters with the application of ion-exchange diaphragms has been conducted by O. S. Lenchevskiy (VODGEO) in collaboration with Ye. B. Trostyanskaya of the Moscow Chemico-Technological Institute imeni Mendeleyev, V. S. Titov of the Scientific Research Institute of Plastics, and M. A. Orzherovskiy of the Black Sea Steamship Co. (Black Sea Shipping Enterprise). Experimental work conducted at a semiplant installation of this type for the conversion of sea water to fresh water has been completed and a full-scale industrial installation for the treatment of Black Sea water by the electrodialysis method is being built.

No information is given on the capacity of the installation mentioned or the quantities of sea water that are being treated or will be treated.[4]

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ITEM 4

DEPARTMENT OF STATE,
*Washington, March 14, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*Committee on Government Operations, House of Representatives.*

DEAR MR. JONES: In response to Mr. Phineas Indritz' request to Mr. Thomas Robinson of the Department for additional data concerning the desalting of sea water research project in Israel we submit the following information:

The United States Information and Educational Exchange Act of 1948, as amended (sec. 1011 of Public Law 402, 80th Cong., as amended), authorized the Government of the United States to guarantee convertibility into United States dollars of foreign currencies received by American enterprises which

[2] High-Molecular Insoluble Polyeletrolytes (Ion-Exchange Resins), by Ye. B. Trostyanskaya and A. B. Pashkov, Khimicheskaya Nauka i Promyshlennost, vol. 2, No. 5, October 1957, pp. 593–602.

[3] Increasing the Economy of Installations for Electrochemical Removal of Salt from Water, by O. S. Lenchevskiy, Cand. Tech. Sci., Sbornik Issledovaniya po Vodopodgotovke [Collection of Articles Investigations on Water Treatment], pp. 174–208, Promstroyizdat, 1956.

[4] Purification of Water and Water Treatment in the U. S. S. R., by V. A. Klyachko, Vodosnabzheniye i Sanitarnaya Tekhnika, No. 11, November 1957, pp. 20–22.

produce or distribute abroad informational mediums consistent with United States interest. Such a program is being conducted in Israel pursuant to an agreement entered into between the respective Governments of the United States and Israel effective June 9, 1952.

The Government of Israel and the Government of the United States agreed, effective June 9, 1952, that funds generated by this informational mediums guaranty program would be used in Israel for cultural, scientific, and educational purposes, among others. In 1957, pursuant to this authority, the Congress of the United States appropriated certain funds to purchase Israeli pounds generated by the above-cited IMG program (Public Law 85–170, 85th Cong.). It was the sense of the Congress that the Israeli pounds, so purchased, be used in Israel for certain cultural, scientific, and educational projects (see p. 232, supplemental appropriation bill of 1958, hearings before the subcommittees of the Committee on Appropriations, House of Representatives, 85th Cong., 1st sess.).

There were 42 specific projects presented to Congress during the hearings on the supplemental appropriations bill for fiscal year 1958 (Public Law 85–170, 85th Cong.). Among those 42 projects was 1 providing for a grant to Israeli research institutions for conducting research in the desalting of sea water. The project, as described before both Senate and House Appropriations Committees (see p. 244, supplemental appropriation bill of 1958, hearings before the subcommittees of the Committee on Appropriations, House of Representatives, 85th Cong., 1st sess.), was as follows:

"Water desalting research---------- $111,111

"To finance a program of scientific research and development in the demineralization of brackish and sea water.

"This project is to be carried out through a grant administered by the Weizmann Institute and would be related to the desalination research of the United States Department of the Interior. The results of this study should be of value to both the United States and Israel."

Our Embassy at Tel Aviv has forwarded to us a brief outline of a desalting research project which the Israelis propose undertaking. This project, as outlined, is concerned with the electrodialysis process for desalting brackish waters in arid areas of Israel. In line with a previous understanding we had with the Office of Saline Water, Department of the Interior, we sent this outline over to that Office for its advice and comments. The grant-in-aid for the project has not yet been made by our Embassy; after we receive the Department of the Interior's comments as to the merits of the proposed project we will advise our Embassy accordingly.

If you have any further questions with respect to this project please do not hesitate to ask them.

Sincerely yours,

WILLIAM B. MACOMBER, Jr.,
*Assistant Secretary.*

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ITEM 5

DEPARTMENT OF THE INTERIOR,
GEOLOGICAL SURVEY,
*Washington, D. C., April 25, 1958.*

Hon. ROBERT E. JONES,
*House of Representatives, Washington, D. C.*

DEAR MR. JONES: This is to inform you of the status of Geological Survey reports on saline waters.

Water-supply papers 1374, "Preliminary survey of the saline-water resources of the United States"; and 1365, "Saline water resources of Texas," have been published and are available from the Government Printing Office.

A report entitled "Saline-Water Resources of North Dakota" has been approved for publication as a water-supply paper and is now with the editors. This report is scheduled to go to the printer this fiscal year for publication as water-supply paper 1428. Typewritten copies of the manuscript are on file for public inspection in this office and in our Ground Water Branch field office in Grand Forks, N. Dak.

The New Mexico report, entitled "Saline Water in New Mexico" is completed and is now in course of review. It is planned that this report also will be published as a water-supply paper.

Tentative plans have been made to begin work on the Oklahoma saline-water report in fiscal 1959. We hope eventually to cover the entire country with similar State reports.

Sincerely yours,

LUNA B. LEOPOLD,
*Chief Hydraulic Engineer.*

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ITEM 6

FEBRUARY 18, 1958.

Hon. JOHN FOSTER DULLES,
*Secretary of State, Washington, D. C.*

MY DEAR MR. SECRETARY: As you know from our letters of February 4 and February 13, 1958, this subcommittee is engaged in a preliminary study of the Government's saline-water conversion program administered by the Department of the Interior.

In connection with our efforts to gather information on saline-water conversion work being done both here and abroad, we have been referred by the Office of Scientific Counselor of the Australian Embassy to a Mr. A. O. Neville Jones, now attached to the British Government's Department of Scientific and Industrial Research, Lower Regent Street, London. We understand that Mr. Jones has only recently returned to the United Kingdom from this country, after having made a very extensive study of developments here and elsewhere in saline-water conversion.

It would be helpful to the subcommittee to have the benefit of Mr. Jones' knowledge of developments in the field of saline-water conversion. Therefore, it would be greatly appreciated if your Department could approach the British Government with a request for Mr. Jones' views and comments on this subject.

The nature of the data, information, and expert opinion which the subcommittee is assembling is as follows:

1. The current state of progress (both here and abroad) in saline-water conversion;
2. The extent of coordination between the Federal Government, private industry, and other public and private groups, both here and abroad;
3. Whether the rate of progress ought to be accelerated;
4. If so, what particular steps might be advantageously taken by the Government to encourage acceleration; and
5. Various processes under investigation and development, including, to the extent available, data on (*a*) conversion cost estimates; (*b*) quantity of water converted per day; and (*c*) source of salinity of water before and after treatment.

It would be most helpful to us if, in making contact with the British officials, it could be indicated that the subcommittee is very eager to receive whatever information might be had at an early date.

Sincerely yours,

ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee.*

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DEPARTMENT OF STATE,
*Washington, April 16, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*Committee on Government Operations,*
*House of Representatives.*

DEAR MR. JONES: Reference is made to the Department's letter dated March 3, 1958, informing you that the Embassy at London had been instructed to endeavor to obtain any information available regarding the views and studies of Mr. A. O. Neville-Jones on the subject of saline-water conversion.

The Department is now in receipt of a report from the Embassy, the principal paragraph of which reads as follows:

The Embassy has discussed with Mr. A. O. Neville-Jones of the Department of Scientific and Industrial Research the questions submitted for his comment in the instruction under reference. Mr. Neville-Jones has now informed the Em-

bassy that after considering the questions he has concluded that he could not provide any information that would be of particular help to the subcommittee of the House of Representatives. He notes that the points raised by the subcommittee cover an enormous field and says that "both because of pressure of work and for other reasons" he feels unable to comment.

At the time he indicated his inability to comment on the points raised, Mr. Neville-Jones said that he did not have any special knowledge beyond that of individuals working on the problem in the United States who presumably would be available to the committee.

The Department regrets that the Embassy did not succeed in obtaining the information which you requested for the Public Works and Resources Subcommittee.

Sincerely yours,

WILLIAM B. MACOMBER, Jr.,
*Assistant Secretary*
(For the Secretary of State).

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ITEM 7

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE,
*Washington, D. C., April 21, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*Committee on Government Operations,*
*House of Representatives.*

DEAR MR. JONES: On April 16 the Department of Defense made its presentation to your subcommittee on desalting of water. The committee raised two questions with regard to Soviet effort in this area. We have undertaken to investigate this subject and to answer the questions that were raised. Also in this connection, we have called the attention of Mr. Indritz to the existence of recent documentation on this subject.

1. Broadly speaking, the Soviets are following the same methods for desalting of water as are under study and in use in the United States. These methods consist of single- and multiple-effect evaporation; vapor compression desalting; single-stage vacuum desalting; freezing; and surfaceless desalting. The last method is a unique one which consists of spraying saline water directly into a burning furnace, and since there is no heat transfer surface, no scale can collect. The Soviets have apparently abandoned this process because the equipment is bulky and there is a large moisture carryover to the surrounding atmosphere. They are also using solar energy, chemical methods of desalting by the use of ion exchange resins and by electrodialysis, or the membrane method, using electric power during the low load demand periods of electric generating plants. Although the Soviets have been working in this area for many years, we have not spotted any method that is in advance of those known or under development in this country.

2. We have no evidence that the Soviets lead in technical developments in the desalting processes of water.

Respectfully yours,

J. R. TOWNSEND, *Special Assistant.*

APRIL 15, 1958.

## SOVIET RESEARCH ON THE DESALTING OF WATER

### SUMMARY

Research in the Soviet Union on techniques for making fresh water from salt water appears to parallel similar research in the United States. Most of the Soviet research on the desalting of water is done for the benefit of industry rather than agriculture.

In developing methods for making fresh water from salt water, the Soviets have investigated thermal, chemical, and electrodialysis[1] (or membrane) meth-

[1] Electrodialysis—The process of separating compounds or materials by the difference in their rates of diffusion through a colloidal semipermeable membrane. This is accelerated or otherwise modified by placing the membrane between electrodes to which a direct current potential is applied.

ods. While substantial progress has been made, large-scale plants capable of furnishing potable water at economic prices are not just around the corner.

Soviet research on thermal methods for the desalting of water has been conducted over a long period of time and in a variety of ways. The present status of Soviet research on the several types of thermal devices are: (1) the single- and multiple-effect evaporation process is the method most commonly used today in the U. S. S. R.; (2) little research is going on in the U. S. S. R. on the vapor compression method, but minor improvements to existing installations are probably being made at the plant level; (3) the Soviets have found the single-stage method more economical than most other methods, but the process apparently has no great future in the U. S. S. R. because of the limitation on large-scale applications; (4) the Soviets have abandoned the surfaceless method, because the equipment is too bulky and use of the technique results in a large moisture carryover to the atmosphere; (5) during the 1930's and 1940's, several Soviet organizations conducted research on the freezing method without any outstanding success; and (6) the Soviets have concluded that distilling water by means of a solar still is profitable only where fuel is expensive and sources of fresh water are far removed.

Soviet research on chemical methods for the desalting of water has been concerned with (1) precipitation, a method which is receiving little attention, and (2) ion exchange resins, a field in which there appears to be intensive effort in the U. S. S. R. although the Soviets are probably not using this method for the desalting of water in any large-scale installations. This type of research seems to be concentrated on water purification for high-pressure turbines used to generate electric power.

There is a growing interest in the U. S. S. R. in the desalting of water by electrodialysis, and major emphasis seems to be on the production of boiler-feed water for electric powerplants by using electric current from the plant during low-load periods.

## Discussion

### INTRODUCTION

Efficient and economical methods of making salt water fresh are of vital importance to the U. S. S. R. because of its vast arid and semiarid regions, such as central Asia and the coastal area of the Caspian Sea. The major portion of the Soviet effort in saline water research is directed toward achieving benefits for steam powerplants and the chemical industries rather than for agriculture. In general, the same research techniques for making salt water fresh have been investigated by the Soviet Union and the United States, although somewhat different equipment and processes have resulted.

### EARLY SOVIET SALINE WATER CONVERSION

Saline water was being converted to fresh water by solar heat in Russia as early as 1872, and the Russian Army used the fuel-heat distillation process in 1881. One of the world's largest saline water conversion plants of the time, which was built at the city of Baku in 1898–99, had an estimated output of 270,000 gallons of fresh water a day.

### CURRENT SOVIET SALINE WATER RESEARCH

The Soviet Union has expanded its areas of saline water research considerably in recent years. Organizations that have been utilized in this effort include the Krzhizhanovskiy Power Engineering Institute of the Academy of Sciences, U. S. S. R., the All-Union Thermo-Technical Institute, the Leningrad Chemical-Technical Institute, and the Azerbaijan Industrial Institute. Regional research institutes have also been utilized in this research work but, in many instances, published results of their work have not been widely disseminated.

### THERMAL METHODS OF DESALTING

Thermal methods for the desalting of water include processes in which water changes its aggregate state either by evaporation or by freezing. The former is the most widely used method and is by far the most important one of all of those used for making salt water fresh. The latter process, which is the older, has been used by the natives of central Asia and western Siberia since ancient times.

*Vaporization*

In most of the various methods of distillation by vaporization, the operating efficiency of the equipment decreases when scale forms in the boilers and evaporators. In Soviet saline water research, major emphasis is placed on prevention of scale and sludge in distilling equipment and on their economical removal when they do accumulate. Most of the books published by the Soviets on treatment of water for use in steam powerplants or for other industrial purposes contain material on the prevention of scale and corrosion. Soviet research has included work on precipitation and filtration for the removal of gypsum; electrical cathodic protection; and the use of antiscale materials, such as proteins, cellulose derivatives, and tannic acids. Soviet evaporation methods for desalting water include:

*Single-and multiple-effect evaporation.*—Single and multiple effect evaporation is the method most commonly used in the U. S. S. R. today to make salt water fresh. The method was used as far back as 50 years ago. A unit operating on this principle was built at Krasnovodsk in 1904 and a similar one was constructed at Vladivostok in 1905.

*Vapor compression desalting.*—In the U. S. S. R., the desalting of water by vapor compression is known as thermal compression. The Soviets claim that the method was invented in 1904 by Bessonov, a Russian engineer. Auxiliary units in the form of turbocompressors, steam injectors, and piston pumps have been added in more recent years. Both horizontal and vertical types of evaporators have been used. Little research is indicated in current Russia literature, although minor improvements are probably being made regularly at the plant level.

*Single-stage vacuum desalting.*—Considerable Soviet research has been devoted to single-stage vacuum desalting. In this method the saline water is often preheated externally by fuel, electricity, or solar energy. The process requires vacuum-tight equipment and seems to be limited to moderate sized units. While the cost factor of producing fresh water by this method appears to be more reasonable than by many others, it is not of sufficient importance to encourage the widespread use of this process which apparently has no great future in the U. S. S. R.

*Surfaceless desalting.*—Surfaceless desalting, an interesting method of making fresh water from salt water, which was attempted by M. A. Fedessev, consisted of spraying saline water directly into a burning furnace. Since the total area inside of the furnace that is covered by droplets is large, the rate of evaporation is high, and there is no heat-transfer surface on which scale can collect. The Soviets appear to have abandoned this process, because the equipment is bulky and there is a large moisture carryover to the atmosphere.

*Freezing*

Few recent research projects on the desalting of water by freezing have been reported in the U. S. S. R. This process has been used since ancient times by various people who have lived in dry climates where the nights are cold and frosty. In this method, salt water is run into ditches covered with stones or boards and, after partial freezing, the ice is moved to other ditches or containers. A number of research organizations in the U. S. S. R. worked on this process during the 1930's and 1940's without any outstanding success.

UTILIZATION OF SOLAR ENERGY IN THERMAL METHODS OF THE DESALTING OF WATER

Much of the recent published research covering thermal processes involves Soviet efforts to utilize solar energy for the production of steam power or fresh water for industrial uses. Research in this field is led by V. A. Baum, doctor of technical sciences, head of the heliotechnical laboratory of the Krzhizhanovskiy Institute in Moscow.

In 1954, at the symposium on solar energy and wind power held in New Delhi, India, Baum presented a paper on work being done at the Tashkent (Uzbek, S. S. R.) Station of the heliotechnical laboratory. The most notable revelation involved the development of a solar boiler utilizing paraboloid reflectors 10 meters in diameter which were said to produce 130 pounds of steam an hour at a pressure of 100 pounds per square inch. This boiler served as a model for the construction of a large-scale still which the Soviets claimed produced approximately 270 gallons of distilled water a day for livestock in the remote and arid Karakum Desert.

Baum also reported that the Soviets had a portable solar furnace that could distill 6 liters of water an hour or cook a meal. The furnace was designed for the use of families of 3 to 4 members.

On March 7, 1957, Baum told the staff of the Egyptian Research Center about the latest Soviet use of solar energy. He probably discussed the production of fresh water from salt water, since an Egyptian delegate to the New Delhi symposium stated that his country's principal concern with solar energy is focused on this problem.

Baum has been characterized as a power engineer of considerable competence whose appearance and presentation of a paper at the 1954 New Delhi symposium had quite an impact on western scientists. There has been conjecture that perhaps the apparent lack of real appreciation of his talents in the U. S. S. R. reflects the low priority given to his projects and to the heliotechnical laboratory. As a result of the paper he delivered at the 1955 World Symposium on Applied Solar Energy in Phoenix, Ariz., western scientists have a somewhat lower estimation of Baum's work than they had up to that time. His paper, which was on the design of a heliostation, was considered largely visionary.

In all of this work on the utilization of solar energy, the desalting of water occupies an apparently incidental position. Touching briefly on the subject in his Phoenix paper, Baum concluded that distilling water by means of a solar still would be profitable only where fuel is expensive and sources of fresh water far removed.

### CHEMICAL METHODS OF DESALTING

Precipitation and ion exchange are the two chemical methods most commonly used by the Soviets in the desalting of water. Little research has been done in the U. S. S. R. up to the present time on the desalting of water by precipitation. An intensive effort appears to be underway in the Soviet Union in the field of ion exchange. Despite this intensive effort, it is extremely doubtful that the Soviets are utilizing ion-exchange resins for desalting water in any large-scale installation. It is highly unlikely that the Soviets at present have the ion-exchange resins or the know-how to produce a facility capable of making fresh water from salt water on such a scale.

The principal application for ion-exchange resins in the U. S. S. R. at the present time appears to be in the field of water purification for use in high-pressure turbines that generate electric power. This process appears to be one of demineralization of normal water rather than one of the desalting of water with a high salt content. The use of ion-exchange resins, however, appears to be a popular topic for discussion.

The Soviet press has, on several occasions, pointed out that ion-exchange resins would be used to purify water in many of the Soviet virgin lands where there is an abundance of water that cannot be used because of its salt content. The press also criticized the Ministry of Chemical Industry for not producing enough ion-exchange resins.

Basic research on ion-exchange resins is being conducted in Moscow at the Institute of High Molecular Compounds, the Vinogradov Institute, and the Institute of Physical Chemistry imeni Karpow.

Most of the applied research in the U. S. S. R., in connection with demineralization or the desalting of water has been done at two organizations, (1) the Section of Water Treatment, Commission on High-Pressure Steam, Institute of Power Engineering, Academy of Sciences, U. S. S. R., and (2) the Commission on Chromatography attached to the Department of Chemical Sciences, Academy of Sciences, U. S. S. R.

Ion-exchange resins alone probably have not proven economical or practical for the desalting of water in the U. S. S. R. If cost is not of great importance and if a large percentage of the purified water can be sacrificed in the regeneration process, there are significant factors that favor the use of ion-exchange resins. These factors are that the equipment (1) is neither complicated nor expensive to design and operate, and (2) require no power, such as heat or electricity.

### DESALTING BY ELECTRODIALYSIS, OR THE MEMBRANE METHOD

There are indications of a growing interest in the U. S. S. R. in the desalting of water by electrodialysis, or the membrane method. The major research effort appears to be directed toward the production of boiler-feed water for electric-power plants by using electric current from the plant during low-load periods. The All-Union Thermo-Technical Institute has developed a multistate cylindrical

desalter which uses ceramic membranes and the Leningrad Chemical-Technological Institute has produced a unit which has cellulose acetate gauze separated by a paper interlayer for its cathode membrane and several layers of bakelite paper for the anode membrane.

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## Appendix B—Inquiries Addressed to Organizations and Individuals, and Responses Thereto

The subcommittee chairman addressed inquiries to a number of organizations and individuals known to be interested in saline-water conversion. These letters requested information and views from the addressees, as follows:

1. The current state of progress (both here and abroad) in saline water conversion;
2. The extent of coordination between the Federal Government, private industry, and other public and private groups, both here and abroad;
3. Whether the rate of progress ought to be accelerated either in basic research or in engineering applications of known processes, or both; and, if funds are limited, whether basic research or engineering applications should be emphasized;
4. Assuming progress should be hastened, what particular steps might be advantageously taken by the Government to encourage acceleration; and
5. Various processes under investigation and development, including, to the extent available, data on (*a*) conversion cost estimates, including all cost components on which the estimates are based; (*b*) quantity of water converted per day; and (*c*) source and salinity of water before and after treatment.

The letters printed below were received by the subcommittee in response to the chairman's inquiries:

Applied Science Laboratories, Inc.,
*State College, Pa., March 4, 1958.*

Congressman Robert E. Jones,
*Chairman, Public Works and Resources Subcommittee,*
*Washington, D. C.*

Dear Congressman Jones: I am happy to respond to your inquiry of February 20 about saline-water conversion. I believe this activity is far more important than has been generally recognized. It is important to the Nation because, except for your own part of the country, water will become a limiting factor to industry and population within 25 to 50 years. It is already such in certain areas, including some that are not considered arid. Even water-rich Alabama may look longingly at the salty gulf, if industry and people keep coming in as I understand they are, from the remarks of my chemist friends in your State.

Saline-water conversion is also important now because of its international political significance. A real success in this area, with proper public-relations action would be a greater achievement than sputnik, since most of the most critical political areas would be tremendously benefited by an increased supply of water. Even the active support of a modest research-and-development program on saline water would be worth the money as a public-relations gesture, before any results were turned in. More good sweet water is good, with no aspect of war or evil associated with it.

With regard to your specific questions my answers are as follows:

1. Progress on development of standard and obvious methods (distillation, ion membrane) has been excellent. There has been limited progress in evaluating less well known processes (freezing, extraction) largely because of limited funds. There has been poor progress on exploratory re-

search because of limited funds and because of a policy of requiring definitely formulated proposals and plans as a basis for support. The latter automatically acts to exclude really big new ideas. I would be happy to explain this further. It is extremely important.

2. Coordination has been excellent in every respect. As the result of the activities of the Office of Saline Water it is easy to quickly become acquainted with all aspects of past and current activity. A few persons and organizations have withheld detailed information, which is of course entirely within their rights. In some few cases extensive claims have been made without disclosing technical or cost details or demonstrating operability. This is a well-known technique for attracting attention for sales or promotional purposes. I would say that the saline-water program has been outstandingly good as far as coordination was concerned.

3. I feel very strongly that a continuing program of basic and exploratory research should be supported, and that if only limited funds can be made available, then the funds should be given to basic and exploratory research (in preference to engineering applications). Research is where the big breakthrough will arise, to give really low-cost water with resultant benefits—both direct and via international prestige for our kind of government. Support of engineering applications should be restricted to pilot-plant operations, for such processes that justify this. This preference for basic and exploratory research is also extremely important. In expressing it, I feel like a lone voice calling in the wilderness, since almost all agencies prepared to finance technical activities give preference to hardware and definitely specified ideas and plans.

4. All that is necessary is a somewhat higher rate of expenditure, continued regularly for another 5 years, plus a continuation of the coordination activity, and active attempts to encourage private activity. The money needed is of the order of two one-thousandths of 1 percent of the annual budget.

5. I have no information on processes that have not already been transmitted to the Office of Saline Water. My own personal work has been basic research on the freezing process, plus a start on exploratory research on entirely new methods. Results of this work are included in reports to the Office of Saline Water.

I am enclosing a reprint of a letter to the editor expressing additional views on this subject. I sincerely hope that your committee avoids any situation that would provide wide publicity for private promotional activities, especially in connection with unsupported factual data or criticism.

I am also enclosing a copy of a telegram to Senator Anderson, of New Mexico, relative to his remarks on saline water conversion in the Congressional Record for January 9, 1958.

I commend your committee on its factfinding approach and its interest in this very important program. Please let me know if I can be of assistance in any way.

Sincerely,

ARTHUR ROSE, *President.*

LETTERS TO THE EDITOR

[Chemical Engineering Progress (vol. 54, No. 1), January 1958]

SALINE WATER COVERAGE LEAVES BITTER TASTE

The recent saline water symposium (Washington, D. C., sponsored by the Office of Saline Water, Department of Interior, and National Research Council) was an excellent high-level scientific affair, with good papers and important discussion both on the floor and in the corridors. I feel certain it greatly stimulated all those present, and that important advances will be made as the result of cross fertilization of ideas.

The conference also demonstrated that the technical and scientific program of the Office of Saline Water has been well conceived and executed. Two distinct types of novel distillation pilot plants (Hickman's and Badger's) are actually constructed and under test at a Harbor Island, N. C., experimental facility. A large laboratory freezing unit is in operation at the Carrier Corp., in Syracuse. It is in my opinion a truly astounding advance to have engineers of the caliber of Badger seriously propose distillation process water costs of 25

cents per 1,000 gallons. This is within the ultimate target range. Of course Badger is probably optimistic; many of us think his figures are low, but everyone should consider that engineers are at least seriously debating about cost figures that are near the target.

The symposium also indicated that the program of the OSW has stimulated industrial interest and activity on desalinization. On the Pacific coast a large utility is setting up a combined power generating and desalinization plant. At the other end of the picture, possibly the most important outcome of the OSW program may well be a real breakthrough in the way of a novel approach to this whole problem, conceived by one of the scientists who started work on the problem because of OSW stimulus.

And all of this has been done by OSW with a very modest budget—a few hundred thousand a year. Except for the pilot plants, which were naturally expensive (a couple of hundred thousand each—certainly not jet plane or missile money), the money was parcelled out a few thousand here and there.

Much of the above was completely missed or ignored by the lay press. Their reports completely and totally missed (1) the spirit and (2) the significance of the meeting.

In my opinion the greatest misunderstanding arose from the attention given by the press to individuals and groups claiming even lower costs for demineralized water produced by their systems, but making such claims in the absence of supportive data. This situation was further compounded by the emphasis given by the press to the fact that these persons claiming such low figures had not been asked to participate in the symposium.

Granted that this meeting was on a subject of wide interest, it is deplorable that it had to be depicted as one around which such claims and counterclaims were associated.

One of the ill effects of this will be that the layman and the Congressmen cannot help but end up with the idea that the OSW program has been poorly carried out and has accomplished nothing. Agents of the U. S. S. R. could not do a better job of misrepresentation of the facts in such a way as to degrate United States efforts. Thus, because of poor reporting, the next Congress will probably end up wrangling around about the OSW program, instead of supporting it adequately. A real success in this area, with proper publicity, would be a greater achievement than sputnik, since all of the most critical political areas would be tremendously benefited by an increased supply of water.

ARTHUR ROSE, *State College, Pa.*

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STATE COLLEGE, PA.

Senator CLINTON ANDERSON,
*United States Senate, Washington, D. C.:*

Have just read with great interest your discussion on saline water conversion in Congressional Record for January 9, 1958. Low-cost saline water conversion is a most difficult scientific problem but as you point out the need is great and the potential benefits are immense both nationally and internationally. A real breakthrough would exceed sputnik in its impact on foreign relations. Sweet water is all goodness with no aspect of war or damage. The United States saline water research and development program has made remarkable progress with very limited funds. Its staff is to be congratulated for their efficiency in distributing limited resources over the many possible research avenues and in stimulating practical technical activities. The symposium discussions last fall indicated clearly that the program is ready for a higher level of activity. Your Senate resolution is wisely conceived since the program is certainly ready for pilot-plant activity. However, it is too early to put all the eggs in one basket. Several processes justify pilot-plant activity and exploratory research should also be pushed hard since the costs are relatively low and the payoff on a research breakthrough would be tremendous. Any one idea is a poor bet, but one idea leads to another, and a more intensive program has every prospect of developing a big improvement. The great idea may come from either research or pilot-plant development, only heaven knows. I urge you to modify your bill to provide for three pilot plants plus exploratory research of one to two hundred thousand per year. It seems urgent because of international aspect, and the costs are relatively very modest compared with missiles and nucleonics.

ARTHUR ROSE,
*President, Applied Science Laboratories, Inc.*

STATE COLLEGE, PA., *April 16, 1958.*

Congressman ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*Washington, D. C.:*

Your committee hearings on saline water conversion have major import for long-term well-being of our country. Sweet water is as important as oil in America, the Middle East, and elsewhere. Even now some of our Middle Atlantic Coast States are unable to expand industry because of marginal water supply. California Legislature is deadlocked because water rich northern areas recognize supply is barely adequate for their own projected growth. Ample water is essential to keep our economy rolling smoothly and strongly forward so we can maintain world leadership without question.

Congressional support to date of the saline water conversion program has permitted major progress on an extremely difficult technical problem. Cost of production of most heavy chemicals is one or more cents per pound. Compare this with three one-hundredths cent per pound that is achieved and one one-thousandth cent per pound goal for making good water from saline water. Salt water is end product of ages of energy degradation.

Raising this chemical system from its existing low energy level to the usable level of sweet water at such low cost is an unbelievably difficult task. Scientists and engineers face many discouragements in this development and need all the help and encouragement you and others can give. The job can be done with the understanding, enthusiastic, patient support of your committee and your colleagues in Congress.

Saline Water Office needs somewhat larger appropriation than in past to keep all interested, competent scientists and engineers on the job continuously. Program should provide amply for research seeking new, much cheaper methods than any yet invented. Only heaven knows whether such cheaper methods are possible. But we may never know if we do not get people searching and thinking and have faith. This research is essential if we are ever to get low-cost saline water conversion. The known processes just cannot give really low-cost water, but until and unless research shows a cheaper way, distillation, freezing, solar, and membrane processes must be tested with pilot plants. Besides research, the program should provide funds for several pilot plants, but these should certainly be based on the processes already studies on small scale by Saline Water Office. Adequate small-scale testing should precede pilot plants for other recently proposed distillation processes. No need to use public funds to build pilot plants based on designs and processes already in commercial production or combining and enlarging existing units. All these give high-cost water, and large sizes can be produced in routine manner any time an emergency warrants these high-cost units. Strong approval and support of a saline water program by your committee and provision of ample funds for its research and pilot plants is not just another minor budget hassle. It is important enough to unbalance national budget to the extent of the few thousandths of 1 percent that is required. Good water to drink for people, animals, vegetation, and industry is more important than missiles to Mars or the Moon.

ARTHUR ROSE,
*President, Applied Science Laboratories, Inc., State College, Pa.*

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ARMOUR RESEARCH FOUNDATION OF ILLINOIS INSTITUTE OF TECHNOLOGY,
*Chicago, Ill., March 5, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*House of Representatives, Washington, D. C.*

DEAR SIR: In reply to your letter of inquiry of February 20, 1958, regarding saline water, the following comments have been sbumitted by our Mr. E. G. Fochtman, supervisor of chemical engineering research, who has been closely associated with the foundation's activities in this area.

Armour Research Foundation has been interested in the conversion of saline water for many years and has conducted a feasibility study for the Interior Department's Office of Saline Water about 2 years ago. We have conducted a

number of other studies involving brackish water purification, conservation of water, purification of water wastes, etc.

We are certain your committee is aware that there are many proven pieces of equipment for the conversion of saline water and that these are commercially available. The problem is one of capital and operating costs. The many commercial firms made it difficult to conduct studies without charges of favoritism. In reality, each commercial piece of equipment may have special advantages in certain applications. The eagerness of some of the manufacturers has lead to misleading broad claims which further confuses the picture.

In answer to the specific questions:

1. Although considerable progress has been made in the past few years, it appears that foreign progress is at least equivalent to United States progress in the recovery of brackish water. Large-scale foreign plants are stated to be ready for operation; however, the United States has conducted only limited studies in this area.

2. The lack of sufficient funds for the rapid evaluation of the various equipment of private industry has resulted in some impatience on the part of industry. In general, the cooperation of the various groups involved in the problem is satisfactory.

3. In some areas basic research should be accelerated; as for instance in freeze purification and in electrodialysis membrane research. Present pilot studies are well advised but should be increased to include solar distillation. These studies should be carefully reviewed each year and discontinued as soon as definitive information is obtained. In view of our present state of knowledge and the degree of urgency of the problem, it is believed that considerable basic research effort is required.

4. Progress on the conversion of saline water can be hastened by increasing both basic research and engineering research programs.

5. Cost of conversion is the important feature in these studies. During a recent program we had occasion to study the estimated costs for a number of projects. We noted that, in spite of the Office of Saline Water's attempt to standardize procedures, many of the estimates were based upon assumptions which were subject to question. In some cases plants have been sized to give a favorable estimate depending upon the relationship of fixed costs and operating costs. Although some of these facts are pointed out by those concerned, others neglect to indicate assumptions or weaknesses in their estimates. Much more information is required before a firm evaluation of costs will be possible.

If we can be of further assistance to you and your committee in this matter, we shall be only too happy to do so since this is a subject of exceptional interest to our organization.

Yours very truly,

L. C. KINNEY,
*Assistant Manager,*
*Chemistry and Chemical Engineering Research Department.*

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ASSOCIATION FOR APPLIED SOLAR ENERGY,
*Phoenix, Ariz., March 3, 1958.*

Mr. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*House Office Building, Washington, D. C.*

DEAR MR. JONES: In reply to your letter of February 21, it is my opinion that Mr. David Jenkins, of the Office of Saline Water, Department of the Interior, is better informed than anyone else in the United States on the subject of the conversion of salt water to fresh water for both drinking and irrigation purposes. However, I can perhaps add somewhat to your stock of information on the international phases of the problem, since our association receives information from its members in all parts of the world.

To answer the first question, and to restrict my replies to the subject of solar energy, interesting work on a small scale is going forward in a number of countries which border on the Mediterranean. At the French Solar Energy Laboratory at Mont Louis, Prof. Felix Trombe and his associates are conducting small-scale experiments on the direct use of salt water for supplying fresh water to plants which are grown within solar stills. The principle of operation is precisely the same as that of the solar stills which have been described in the annual reports of the Office of Saline Water, but the French development is

unusual in that the distilled water is conducted immediately to the beds in which the plants are being grown. Thus far, the work has been carried out only on a small scale, but it appears to me to be worth additional attention, because of the current availability of weatherable plastic films which could well be used in place of the glass employed in the French experiments.

Small solar stills are being used to provide drinking water in arid areas, such as the island of Malta, Cyprus, and in Algeria. Solar stills designed by Dr. Maria Telkes have been displayed in trade fairs sponsored by the Office of International Trade Fairs, and displays sponsored by the United States Information Service at Salonika and in Athens. These same solar stills will be displayed at the forthcoming trade fair in Casablanca, Morocco.

A large solar still is now being considered for installation on an island adjacent to Athens, where a boys' camp is operated during the summer. There is no water whatsoever on this island, and the Du Pont Co. is interested in the possibility of using this as a testing ground for the large stills which are being designed to use their plastic materials.

To comment on your second question, the Office of Saline Water is, as you know, coordinating the relations between the Federal Government in the United States and both in private industry and college groups. Abroad, the French work is under the general supervision of the Government, but Dr. Trombe works with a very free hand, and turns his attention to projects which draw his interest.

In Italy, a private company, Somor, at Lecco, is producing solar-powered pumps which are being used to some extent in the Sahara for pumping irrigation water. Our association has borrowed one such pump from the Somor Co., and it is now assigned to Arizona State College in Tempe. If our present plans work out, this pump will be used to test the feasibility of using solar heat in the compression distillation cycle. It is our belief that this cycle has a considerable amount of merit, in that it appears to be possible to produce considerably more water for a given collection area than with the direct solar-distillation method. It has been our policy to keep Mr. Jenkins informed of projects which we contemplate in the field of solar stills, and our association has also worked closely with the Du Pont Co. in this field.

In reply to the third question, I feel very strongly that the rate of progress ought to be accelerated by applying more funds both to basic research and in the engineering applications of known processes. If there must be a choice at this time, I would favor the latter, because there are a number of ideas which can only be proven through the operation of fairly large equipment. Again, I refer to the solar stills, which have, thus far, only been operated in very small sizes. It would have been wise, for example, if the original San Diego project of the Office of Saline Water could have been carried to completion, because there would have been an excellent opportunity for cooperation between that Office and the Du Pont Co., under the terms of which a large plastic solar still could have been erected and tested at relatively small cost to the Government.

The problem of turning salt water into potable or irrigation water is a major one, and, like the guided-missile program, it cannot be operated on a rigid time schedule. The solving of the problem depends upon two major factors, the first of which is the obtaining of new ideas, and the second is the actual building and testing of apparatus.

In order to reply to the fourth question, it is my opinion that the most important step to be taken now is the testing of fairly large-scale apparatus. In the field of solar energy, particularly, no large solar still has been built since 1870, and the improved designs which are available today should certainly be tested on a large enough scale so that the actual operation problems can be defined.

The best reply to question 5 will be the forthcoming annual report of the Office of Saline Water. Mr. Jenkins and the scientists on his staff have more information on these factors than any other source in the world, and I am sure that your committee will give them a sympathetic hearing.

It is my personal feeling that the best way to get ahead on the job of converting salt water to fresh would be to give adequate financing to the Office of Saline Water, and then let Mr. Jenkins and his colleagues concentrate on this job. To the best of my knowledge, he has considered virtually every possible way by which salt water can be turned into fresh water, and he is concentrating on those methods which, in the opinion of the best-qualified experts in this country, give most promise of a good solution to the problem.

Very truly yours,

JOHN I. YELLOTT, *Executive Director.*

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BATTELLE MEMORIAL INSTITUTE,
*Columbus, Ohio, February 26, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee of the Committee on Government Operations, House of Representatives, Washington, D. C.*

MY DEAR MR. JONES: This is in reply to your letter of February 20 concerning progress in the Federal Government's saline-water-conversion program.

1. The current state of progress both here and abroad was recently described at the symposium on saline-water conversion held in Washington on November 4–6, 1957. The proceedings of this symposium unquestionably present the most authoritative appraisal of the state of progress. These should be available shortly.

2. The Office of Saline Water, besides administering the basic research and the studies on engineering applications, has also coordinated to a large extent the activities of private industry and other groups, along with those of the Federal Government. We believe that this job has been well done in the sense that any proposal for study has been competently appraised and all encouragement given whenever the appraisal justified this policy. Information has also been obtained on most or all foreign developments in this area.

3. We believe that basic research should continue on all projects which show promise of solving the technical problem irrespective of whether, at first sight, the costs seem excessive until sufficient data have been obtained to supply all of the technical information for conversion. Ideas involving a new basic approach should also be investigated to demonstrate their technical feasibility. Engineering application studies should be pursued on known processes at a pilot plant scale sufficient to yield reliable cost data. If the program is to be accelerated, the effort should be placed both on basic research and on engineering studies. Also, we believe that it will be found that radically new basic approaches to this problem will not be numerous so that the main effort will probably actually be placed on engineering studies. If the funds are limited, we believe that priority should continue to go to new basic approaches so that the effect will be a reduction in the rate of progress in engineering studies. This will have the result of delaying the time when the choice of a process, for a given application, can be made with full knowledge of costs.

4. If progress is to be hastened, assuming that all basic research is adequately supported, engineering studies on appropriately scaled pilot units should be made simultaneously on all processes whose technical feasibility has been demonstrated in order to obtain costs.

The possibility that the Federal Government might undertake the establishment of full-scale water-conversion plants in areas lacking water, as a means of accelerating the program, transcends the technical aspects of the matter and is one of engineering economics.

5. Battelle Memorial Institute at the present time is conducting 1 basic research study and 2 studies in engineering applications for the Office of Saline Water.

The basic study has to do with establishing the fundamental process by which salt may be separated from water during freezing. This study is not aimed at establishing cost estimates either in terms of equipment or in terms of capacity.

One of the engineering studies is concerned with the Hickman still which is a variation of the vapor-compression process. The purpose of this study is to establish present performance and to seek ways of improving it. Cost estimates in terms of water-evaporating capacity are the ultimate goals. The application is to sea water and, since this is a distillation process, the salinity of the water produced should be almost nil.

The third project has to do with an engineering study and field evaluation of solar stills. The aim here is to establish the performance on a pilot plant scale of various designs of solar stills that have been proposed or tested on a small scale and, from these studies, to find ways of improving their performance whenever possible. These studies will also yield cost estimates and give data on the quantity of fresh water produced by the units. The application, again, is to sea water and the product should have a nil salinity.

We are glad to have an opportunity to comment on this important work and shall willingly supply further information if desired.

Very truly yours,

B. A. LANDRY,
*Assistant Technical Director.*

BETHLEHEM STEEL CO., INC.,
SHIPBUILDING DIVISION,
*New York, N. Y., March 10, 1958.*

Subject: Research and Development by Bethlehem saline-water conversion.
Enclosure (*a*): Booklet "Bethlehem combined electric generating station[1] and 250,000 gallons per day 4-stage flash distilling plant" dated January 1958.

CONGRESS OF THE UNITED STATES,
*House of Representatives, Public Works and Resources Subcommittee of the Committee on Government Operations, Washington, D. C.*

(Attention: Mr. Robert E. Jones, Chairman, Public Works and Resources Subcommittee.)

GENTLEMEN: We refer to your letter of February 21, 1958, wherein you request views and information relating to the research and development conducted by the Bethlehem Steel Co. in the saline-water-conversion problem, and are pleased to offer herewith the following information:

Based on 20 years experience building multiple-effect submerged tube distilling units and 10 years experience building multistage flash distilling units for marine installation, Bethlehem is now quoting and guaranteeing performance of flash-type distilling units for shore installations.

The flash-type unit is well past the research and development stage and Bethlehem has made firm proposals on a number of plants ranging up to 1,200,000 gallons per day. Many of these proposals have been for plants to operate in conjunction with a steam electric generating station using the exhaust steam from the generator turbine in the flash distilling plant.

Enclosure (a) is such a proposal for a 250,000-gallons-per-day 4-stage flash-type unit combined with a 2,500-kilowatt turbogenerator. As stated on page 2 of enclosure (a), the operating cost of making fresh water including fuel, labor, maintenance, and supervision is $0.87 per 1,000 gallons. With larger plants of about 1,000,000-gallons-per-day capacity having an increased number of stages, this cost would be reduced to about $0.40 per 1,000 gallons. Overall cost of producing fresh water including amortization and interest on the investment would be about $0.75 per 1,000 gallons depending upon interest rate and period of amortization. One such proposal was made to the British crown agents for an 8-stage flash-type distilling plant to operate in conjunction with an electric generating station for producing 1,200,000 gallons of distilled water per day and up to 10,000 kilowatts of electric power for installation at Nassau, Bahama Islands. The operating cost (fuel, labor, maintenance, and supervision) of producing water with this plant was $0.40 per 1,000 gallons.

The following relates to the specific information requested in the fourth paragraph of your letter of February 21, 1958:

1. The current state of progress as far as Bethlehem is concerned is as outlined above; i. e., Bethlehem is now quoting on a fixed-price basis on flash-type distilling plants having guaranteed fresh-water capacities of more than a million gallons per day with a salinity of not greater than 0.25 grains per gallon (4.3 parts per million). No further research is required in the flash process. Plants operating on this process have been giving satisfactory service on ships at sea for over 10 years.

2. There has been no coordination between the Government and Bethlehem. Both the submerged-tube and the flash-type distilling plant were developed and patented by Bethlehem first for shipboard use and later adapted for shore installation.

3. With limited funds available, it would appear desirable to use those funds for constructing distilling plants of large capacity to obtain service experience. Contracts should be on a fixed-price basis and on firm guaranties. To realize maximum economy, these plants should preferably use exhaust steam from electric-generator turbines. The ideal locations for such installations, therefore, are those at which a requirements exists for both water and electric power, Construction of such plants would give reliable data on overall costs, both operating and fixed charges.

4. See paragraph 3.

5. See previous text and enclosure (a).

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[1] The enclosure is available in the files of the Subcommittee on Public Works and Resources.

We trust that the above information will adequately cover your requirements relative to this problem.

Yours very truly,

H. K. BARTOW.
*Manager, Special Products Sales.*

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UNIVERSITY OF CALIFORNIA,
DEPARTMENT OF ENGINEERING,
*Berkeley, Calif., March 6, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*House Office Building, Washington, D. C.*

DEAR SIR: This will respond to your letter regarding progress in the field of saline-water conversion. The following comments are presented in answer to your specific questions:

1. *Current state of progress.*—This became evident at the recent symposium held in Washington last November. A summary prepared for a committee of the California State Legislature is enclosed for your information. My personal conclusions will be found on pages 7, 8, 9 of this material.

2. *Extent of coordination.*—I can speak positively only for the U. C. program. We have many visitors to our research station and try to give full information. Representatives of the Saline Water Office were in Berkeley on two occasions during the calendar year 1957. I personally visited the OSW in Washington twice during the same period and also called on at least five other research groups engaged in this activity. Exchanges of information by letter with others in the United States of America and in other countries have been fairly numerous.

3. *Need for acceleration.*—In California it has been stated that conclusions as to the feasibility of desalting processes must be firmed up within the next 8 to 10 years. So far as the local program is concerned, this will require an acceleration of work at U. C.

4. *Encouragement of acceleration.*—This can probably best be accomplished through the activities of the OSW in soliciting cooperative projects with competent research groups. This should be possible if funds are made available for such contracts as well as for additional staff work in the OSW, if the latter is found necessary.

5. *State of the art.*—The situation as I see it is summarized in the enclosure. The commercial plants in existence so far include several multieffect distillers, with capacities up to 2.7 million gallons per day; several vapor-compression plants producing up to 200,000 gallons per day each; and several electrodialysis plants, one of which will soon deliver 2.8 million gallons per day. None of these large plants is located in continental United States of America.

So far as costs are concerned, the minimum production figure for the foreign installations mentioned is $1.75 per thousand gallons. From the experimental program at U. C. we have the impression that several of the processes under study here may ultimately approach the price goal of $100 per acre-foot, specifically the low-temperature-difference system where two water sources are available, the capillary-membrane process, and the modified ion-exchange system.

It is my personal impression that commercial designers and manufacturers will accomplish substantial improvements in costs and economy of multieffect distiller plants (both submerged-coil and flash types) and in vapor-compression equipments. However, these improvements are estimated by people in that field to promise at best a minimum cost of $1 per thousand gallons. If lower costs are to be achieved it would therefore seem that there should be a continued emphasis on basic research on other methods and an early transition to pilot-plant status of any which may be promising.

I hope the above comments may be of interest.

Yours very truly,

EVERETT D. HOWE, *Professor.*

## Salt Water Conversion Research Program

Prepared by Everett D. Howe, professor of mechanical engineering, University of California

This program has been underway since 1951–52. Its purpose is to search for methods of demineralizing sea water at a low cost. A tentative price goal of $100 per acre-foot was selected and would place the product in competition with certain natural domestic supplies. Reductions to costs lower than this could result from prototype operation. Because of the high costs of fuel or power for conventional methods of distillation, schemes utilizing waste heat, solar heat, and other forms of nonfuel energy have been studied. Also, some consideration has been given to improvement of existing methods.

The experimental equipment at Richmond consists of the low-temperature-difference plant, the solar plant, and a small chemical laboratory and computing room. Some laboratory space on the campus is also being used for osmotic-pressure studies. The research being done is as follows:

*A. Berkeley campus and Richmond*

1. *Low-temperature-difference plant.*—A scheme for using 2 sources of water at different temperatures, say from 15 to 30 Fahrenheit degrees apart. The present plant consists of a vacuum flash chamber 12 feet in diameter with appropriate conventional pumps and condenser. It has a present capacity of some 2,000 gallons per day, and is limited by the carryover of both fog droplets and air to the condenser. Experiments presently being executed are directed toward the reductions of these carryovers and should increase the capacity considerably. Estimated costs are favorable.

2. *Solar distillation plant.*—This solar plant is the largest one in existence today. It consists of several greenhouse-type units, a wick-type unit, a tubular unit, and a paraffin-absorber unit. Continued operation of the plant for a period of 5 years has resulted in the assembly of considerable performance data as well as information on costs of construction and operation. Costs of water produced are too high because of capital expenditures. As a result of this work, a new type of still is under construction which is expected to produce water at lower costs than previous units.

3. *Ion exchange research.*—The use of chemicals which can be reclaimed by the application of heat has been under study. Exchange materials have been selected which can be regenerated with the use ammonium bicarbonate solutions. Sea water passing through beds of these materials comes out stripped of sodium chloride and the other original minerals but charged with the ammonium bicarbonate. This latter can be driven off by heat and the ammonia gas and carbon dioxide captured and reused. The studies are at the stage where preliminary design estimates are underway and should be significant. So far, the preliminary cost estimates for a very large plant are encouraging.

4. *Reversed osmosis.*—This is a basic research experiment being conducted on the Berkeley campus. The general idea is to produce a sieve of such fine mesh that the salt ions, which are physically larger than the water molecules, will be strained out. Efforts so far are in the direction of constructing sieves of this type and have been moderately successful.

5. *Magnetic effects investigation.*—This is a basic project to determine whether or not scale prevention equipment of the magnetic type could be adapted to the problems of desalting water. Progress to date is limited to some library work and the construction of a small test apparatus.

*B. Los Angeles campus*

This work is coordinated with the work at Berkeley through occasional conferences between the investigators in the two groups. Projects active there include the following:

1. *Reversed osmosis.*—An attempt to use thin films of air or oil as a membrane. A small piece of equipment for testing such membranes has been constructed and is making a small amount of water. The major work consists of work on the production of air-gaps of width about 0.005 inch and large area.

2. *Skimming processes.*—An attempt to skim off the surface of water to a depth of a few molecules only, since the surface layer is comparatively free of the dissolved salts. A piece of apparatus is now operating and produces a small amount of water.

3. *Thermodynamic analysis.*—This is a use of theoretical tools to point out the particular directions in which research on any given method would be most

likely to produce improvements. Some of the findings of this have been most helpful in directing the research.

SUMMARY OF SYMPOSIUM PAPERS

*A. Thermal distillation*

1. W. L. Badger proposes 12 effects of the submerged-coil type using the long tube vertical construction common in the salt industry but not previously applied to sea water distillation. The ultimate in low cost of product is to be realized by using low-carbon steel rather than copper-nickel alloys for the heat exchange surfaces and by preventing scale deposition through the circulation of a crystal slurry in the brine compartments of the evaporators. Estimated production costs amount to 25 to 30 cents per thousand gallons. Experiments are underway to determine the effectiveness of the scale control program and the corrosion resistance of the steel construction.

2. Griscom-Russell proposes the use of single-stage flash for use of waste heat (essentially the low temperature difference method described under the U. C. program) and the use of multistage flash distillation for higher temperature sources. Without giving details of the plant layout, an estimate of 70 cents per thousand gallons was given for cases in which the steam supply is received as the exhaust steam from a powerplant.

3. The Fluor Corp. reported on a study of the possible combination of a nuclear reactor as a low-temperature heat source with a multieffect submerged-coil-type distiller. It was determined that the optimum number of effects would be 7 and that the probable costs of water so produced would be 63 cents per thousand gallons.

4. The Nuclear Development Corp. reported on their experiments on critical pressure distillation. This method has the theoretical advantage that the heat added during the vaporization process is very small at pressures just below the critical value and becomes zero at the critical. This makes it possible to reuse the heat much more efficiently than is possible where the latent heat is large. It was reported that the problems of salt deposition and corrosion were so severe that the experiments were discontinued.

5. Solar distillation was the subject of four reports. Mr. George Löf reported on the design of a 5,000 square foot unit which was designed and sent out for construction bids. The total price bid was $69,800 and included several extraneous items. Since this cost was greater than the money available, the contract was not placed. Cost estimates were discussed and figures advanced by several estimators were cited, the lowest of these being $3.66 per square foot for glass construction and 60 cents per square foot for inflated plastic units.

Mr. Gomella from Algeria and Mr. Wilson from Australia told of the success in production of household-sized units in their respective countries. These units have trays molded from asbestos cement and are covered with glass. Although the unit costs are high, the householders regard them much as people in the United States regard household refrigerators and other appliances. There are several hundred units operating in each country, each unit with a capacity of only a few gallons per day.

Dr. Telkes told of her experiments with the application of the multieffect principle to the solar still. By using a series of layers of absorbent materials and waterproof sheets, it was possible to obtain a considerably increased output per square foot of absorber surface.

The general conclusion was that solar distillation needs very much more development before its production costs can be reduced below the several dollars per thousand gallons which now seems to be true.

*B. Vapor compression distillation*

1. K. C. D. Hickman reported on the development of a centrifugal still, in which the heat transfer surface is rotated to diminish the thickness of water films. It was reported that heat transfer coefficients some five times as large as those for stationary surfaces were obtained. This made possible the use of small temperature differences, increased the efficiency of the process, and led to estimated power consumptions of 60 to 80 kilowatt-hours per thousand gallons of output. A unit of 25,000 gallons per day capacity has been constructed and is to be tested using sea water in the very near future.

2. A. M. Eshaya reported on experimental work on the reduction of the resistance to heat flow in conventional vapor compression plants. Forced circulation of the brine resulted in considerable improvements, as did also the use of lard oil to insure dropwise condensation on the steam side. No experiments on complete plants were made in this research.

*C. Vapor compression using ice*

In this scheme the vapor compressed is that of a refrigerant and the water is frozen, the ice crystals washed or otherwise separated from the brine and then melted. Theoretically, this process should require very little energy because the latent heat of fusion is only one-seventh the latent heat of evaporation.

1. Studies of the use of conventional ice-making machines were carried on at the University of Washington. Professor Hendrickson reported on very extensive studies and experiments made in existing ice plants. His conclusion was that the cost of water from such plants could be as low as $1 per thousand gallons only if the cost of making ice could be reduced to one-ninth of its present value.

2. The Carrier Corp. reported on experiments in direct freezing of the ice. This is accomplished by spraying the sea water into a vacuum chamber. The ice forms as a crystal slush, is pumped out of the evaporator, washed and then melted. The vacuum is maintained in the freezing tank by pumping out the water vapor. Experiments so far indicate that this process can be expected to require power amounting to 26 kilowatt-hours per thousand gallons, and to produce water at figures less than 50c per thousand gallons.

3. Experiments on freezing by the direct injection into sea water of an immiscible volatile liquid were conducted at Cornell University. Professor Wiegandt reported on the use of iso-butane for this purpose. No complete plant has been built but the experiments so far indicate favorable power and cost relationships.

4. Experiments at Pennsylvania State University have been directed to the difficult problem of separating ice crystals from the brine. Professor Rose described the studies of the microstructure of ice, the possible increase in size of ice crystals, and the possibilities of washing off the brine by the use of various liquids. No complete plant was investigated.

5. Zone freezing is being studied at Batelle Institute. Messrs. Himes and Goering reported on studies of the patterns of salt deposition resulting from controlled freezing conditions. These studies are fundamental ones and indicate favorable possibilities. No complete plants were studied as yet.

*D. Use of reversed osmosis*

Experiments at the University of Florida were reported by Professor Reid. Films of cellulose acetate were used with pressures up to and above 30 atmospheres. Fundamental experiments have led to an increased understanding of the phenomenon and the qualities which a suitable membrane must possess. Cellulose acetate was found unsuited to this usage because it hydrolyses. No studies of a complete plant using this process were reported.

*E. Electrodialysis*

Discussions of the theory of the permselective membranes were presented by 3 authors and discussion of plants using these membranes by 3 others.

1. The theory of membrane operation seems to be taking rather definite form. This should enable future development to proceed more rapidly than in the past.

2. The use of electrodialysis in the purification of water pumped from deep mines in South Africa was reported. A 20,000 gallon-per-day pilot plant was operated for nearly 2 years and led to the design of a 2,800,000 gallon-per-day plant now under construction and to be completed about April 1958. The feed water to this plant will have a total salinity of 3,000 parts per million (sea water is 35,000 parts per million) and the desalted water will have a salinity of about 500 parts per million. The cost is estimated at 2s. 6d. per 1,000 Imperial gallons, about 29 cents per thousand United States gallons The cost of the water will be borne partly by the consumers, who will pay 2s. per thousand Imperial gallons (the same price now being paid for river water) and partly by the mine owners, who now pay about 3d. per thousand gallons of feed water for disposal of the saline water as a waste.

3. The development of electrodialysis equipment in the Netherlands was discussed by Mr. Wegelin of T. N. O. Field tests on the Dutch coast were conducted using a 3-stage unit which produced 36 $m.^3$/day (about 9,500 gallons per day). Test conditions ranged from 20,000 to 1,000 parts per million of chlorine and the corresponding power requirement varied from 150 to 4 kilowatt-hours per thousand gallons. No overall cost figures were given. It was stated that a Dutch firm is now ready to install commercial plants.

4. Field operation of equipment built by Ionics, Inc., was reported by Messrs. Juda, Kirkham, and Mason. The largest plant now operating is located in the

Middle East, can produce about 86,000 gallons per day and is being fed with brackish water. Operating experience is also being accumulated with several production units working on sea water.

## SUMMARY

The general objectives of all of the research in the United States are to find one or more methods by which water can be produced at a cost competitive with the costs of natural water supplies and with a minimum rate of fuel consumption.

*Thermal distillation*

There has been no major breakthrough in multieffect distillation. The proposals of Badger probably represent a near ultimate in cost reduction through the use of cheap materials and simplified operational procedures. The use of shell and tube metallic heat exchangers imposes a limitation on the number of effects possible and involves a capital charge for distilling equipment alone in excess of 25 cents per thousand gallons. If the multieffect principle is to be used for water at a lesser cost than the above, it will be essential to find a radically new approach.

The large fuel consumption characteristic of these equipments can be lessened to some extent by the combination with electric-generating plants. The use of nuclear energy gives promise of relief from very large gross fossil fuel consumption where large distilling plants may be justified.

Low-temperature difference plants using vacuum-flash distillation should have a limited application and could probably produce water at a figure approaching $100 per acre-foot after some further development.

Solar distillation, using the simple hood-type units, has been given considerable study. For isolated householders needing a few gallons per day of distilled water it can be justified in the same way as other household appliances. For large-scale purposes the costs are so high that a radically new approach is indicated.

Vapor-compression distillation has been given considerable study and has been substantially improved. However, there has been no major breakthrough and the estimated cost of production has fallen only from about $1.25 in 1949 to about $1 per thousand gallons today. Prospects of further reductions in cost are uncertain.

Combined plants involving steam generation, vapor-compression equipment, and multi-effect-thermal distillation probably represent the most economical plants that can be constructed today. Although several proposals along this line have been made, none have been installed. Production costs would probably approach $1 per thousand gallons, and the water to fuel ratio could approach 400.

Freezing plants seem to have a considerable potential for decreased fuel consumptions, as do also the plants using reversed osmosis. Theoretically, the osmotic-type plant should have the lowest power demand, since no phase change is involved. However, no satisfactory membrane has yet been developed for reversed osmosis.

Electrodialysis is now in the prototype-plant stage of its development. The results so far make it quite attractive for use with brackish water. Continued operation of these plants may make possible more effective application to sea water.

The general situation relative to costs and fuel consumptions is shown in figures 1 and 2. Figure 1 shows as a goal the unit cost of $100 per acre-foot. The ordinates on the curve show the number of acre-feet obtainable for $100, solid lines being used for existing plants or firm figures and dotted lines for estimates.

Figure 2 shows the ratio of water produced to fuel used. The goal of 1,500 pounds of water per pound of equivalent oil fuel used represents an approach factor of about 5 to the theoretical minimum energy required for the separation of fresh water from sea water under ideal conditions. Data from existing plants is shown in solid lines and estimates in dotted lines.

In conclusion, it is essential to keep in mind several important points, namely:

1. Basic research on methods not well developed is essential, even though it may not mature for some time to come.
2. Complete examination of promising methods cannot be accomplished in the research laboratory. It is essential that pilot plants be operated and, in some cases, that small prototype plants be placed on a production schedule.
3. Refinements of construction and operational procedures are productive of cost reductions and generally result from production experience.

FIGURE 1

COST COMPARISON

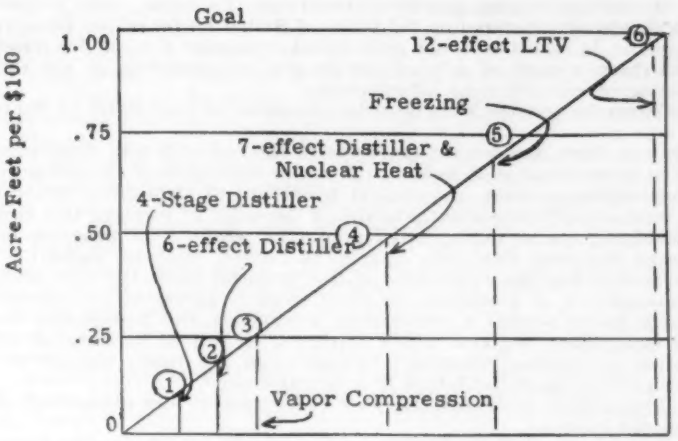
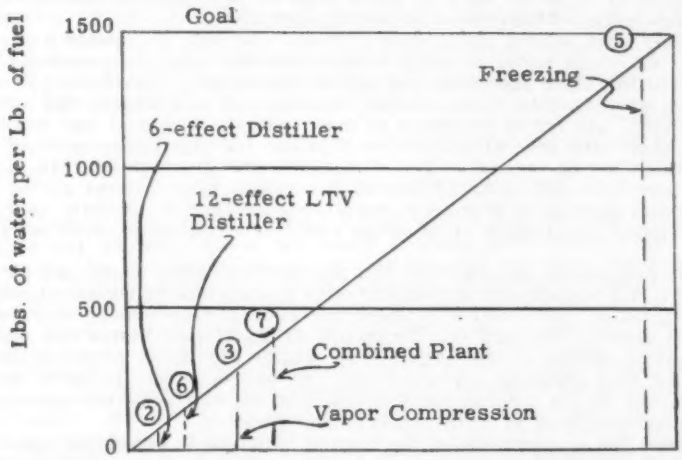



FIGURE 2

FUEL ECONOMY COMPARISON




1. 4-Stage Distiller - Kuwait
2. 6-Effect Distiller - Aruba
3. Vapor Compression
4. 7-Effect Distiller & Nuclear Heat
5. Direct Freezing
6. 12-Effect LTV Distiller
7. Combined Plant

CARRIER CORP.,
*Syracuse, March 5, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*House of Representatives, Washington, D. C.*

DEAR CONGRESSMAN JONES: We are pleased to submit information and our comments in answer to your questions concerning the saline water conversion program which is administered by the Office of Saline Water of the Department of the Interior. In addition to our generalized comments to your five questions we are attaching a copy of a brief descriptive memorandum of the Carrier direct freezing process for your information.

Let us take up the questions in the order presented in your letter of February 21, 1958.

1. At present there are several processes in the research and developmental stages which show promise of meeting the major objectives of the saline water conversion program; namely, a technical feasibility to yield fresh water from sea water, and, equally important, showing a potential of meeting this requirement economically on an extrapolated production scale. The progress in the past 15 years has been slow due, largely, to limited financial support. This support is needed for the evaluation of the essential steps for any proposed method. Completion of a number of these steps is necessary to provide the results which would permit a comparative evaluation and a reduction in the number of candidates to a few which in turn then can be accelerated into a demonstration production capability. These steps are those normal to any new research type project and follow in a logical order.

(1) Preliminary technical analyses (literature review-theoretical study of proposed method).
(2) Design of small laboratory-scale apparatus to determine technical feasibility.
(3) Development of a laboratory model of process.
(4) Design of pilot plant.
(5) Construction and test of pilot-plant operation.
(6) Economic and technical evaluation of process.
(7) Design, fabrication and operation of a production scale plant.

As progress is made on each of these steps it is important continually to evalute the potential of the process to meet the objectives.

There have been several distillation methods available to provide a process for converting saline water to fresh water; however, even in large-scale production facilities, these processes may not be economically justifiable. Several such plants are installed today, mainly abroad, and are serving the specific needs intended. As far as processes to meet both the technical and economic objectives there are several under investigation for the Department of the Interior which are in various stages of research and development. In almost all cases these have not advanced beyond the steps 5, 6, or 7 listed above.

In summary, there is no process to our knowledge that is currently available for production of fresh water from saline water at a cost of 50 cents per 1,000 gallons.

It is our considered opinion that the process now being developed by the Carrier Corp. will be competitive with any other process now under consideration.

2. The extent of coordination between the Federal Government, private industry, and other public and private groups in the United States and abroad has been quite extensive and satisfactory within the limits of expenditures available for this purpose. In particular, the efforts of the Office of Saline Water and the recent International Symposium on Saline Water Conversion have increased the extent of coordination and cooperation.

3. The need for acceleration of the rate of progress is dependent upon the urgency of the needs for applications for the process. For a water supply to meet the specialized need of the military installations, marine vessels, etc., conversion has been accomplished by removing the objective of an economical process. However, for metropolitan, agricultural and industrial utilization, the water supply must be reasonably competitive, economically, with natural sources.

It would appear essential to accelerate the rate of progress in basic research to provide new and improved methods—also to enable an evaluation of the various processes it is advisable to speed the development of processes in engineering application through the steps 5 and 6 above. It is important to draw a close analogy in this field of technological development to the development of com-

petitive electrical power by commercial utilization of nuclear power. The most conservative early estimates of costs of production per kilowatt hours have turned out in actual costs of installed facilities to be 2 to 10 times more than the estimates. Therefore, it is vitally important to progress through the various stages of research and development prior to stepping out into a very large capacity plant, especially if the timing permits a well-planned and organized long-range program.

4. To encourage acceleration, one step is paramount—the availability of increased financial support for research and development and pilot-plant evaluation of processes. A decision can be made then for vigorous development of a production facility to meet one of the apparent urgent needs within our country. A full evaluation of the market potential and urgency of need for a conversion process would generate, and accelerate interest in industrial participation.

5. The objective of any conversion process should be the ability to convert waters with solid content from 40,000 parts per million (saline) and 10,000–15,000 parts per million (brackish) to potable water of 500 parts per million or less at a cost reasonably comparative to domestic delivered water supply. Many cost estimates have been prepared, extrapolated, and quoted, based on many different assumptions. Even those prepared on a standard form of the United States Department of the Interior have an extreme range of assumptions. However, it does seem feasible that a cost summary of the various processes utilizing a set of standard assumptions would give a comparative value of economic potential. These should be based on similar production capacities. Extrapolations are at the best "guesstimates." The contradictory objection to this approach, however, is that it is likely that large capacities, 10–50 million gallons per day, will be essential to reach realistic comparative costs. However, from historical experience extrapolation from small-scale equipment to this extreme is not completely valid. Yet the pilot-scale plant does indicate the feasibility and practical aspects of the process operation at a much lower cost than plunging prematurely into 1 or 2 major construction programs for production capacities. The pilot plant produces from 4,000 to 25,000 gallons per day which provide a representative value of operational characteristics, as well as preliminary costs for the process.

In summary, it is our considered opinion that it would be desirable to put more emphasis on pilot plants and their evaluation before going ahead with full-scale production facilities at this time. It is too early to put all our eggs in 1 or 2 baskets.

It is sincerely hoped that the information provided herein will be helpful to you in your evaluation of the program for saline water conversion.

Yours sincerely,

J. F. Downie Smith,
*Vice President, Research & Development Division.*

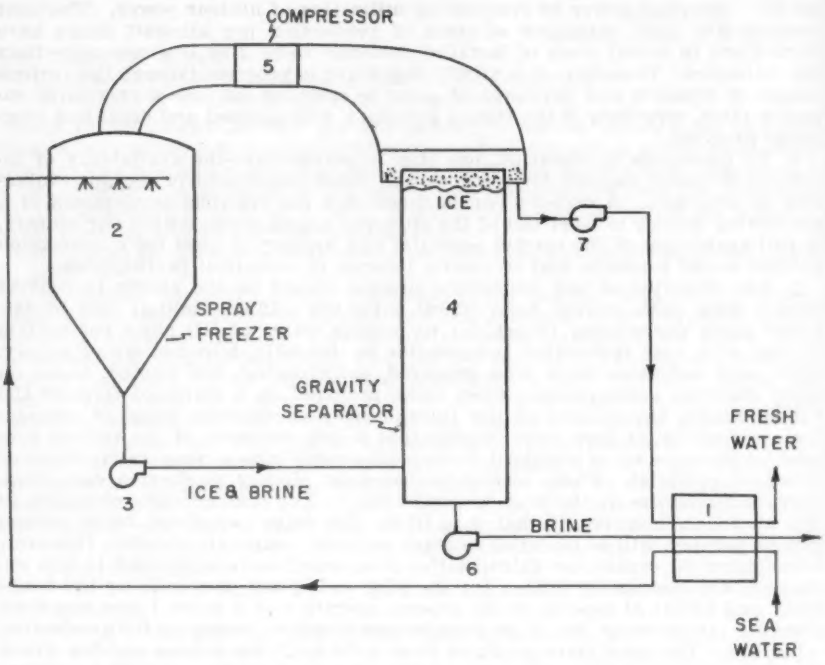
### Carrier Direct Freezing Process

The freeze separation process is based on the fact that ice frozen from salt water and washed free of salt water becomes pure water when melted. In order for the process to become economical, the sea water must be frozen by using a minimum of energy and the ice must be washed inexpensively. A brief description of the process with reference to the diagram follows.

The freeze-separation process uses a novel means of refrigeration. Sea water that has been pre-cooled (1) is sprayed into an evacuated container (2). In this "direct" freezer, a small quantity of the water is evaporated. The evaporation extracts heat from the water and causes part of it to freeze. Because one-seventh of the amount of heat required to boil water must be removed from water to freeze it, about seven times as much ice is formed as water vapor in the direct freezer. The slurry of ice and the brine is pumped (3) to the separator (4). The vapor is then compressed (5).

The ice is washed in the gravity separator (4) with fresh water. The ice floats through the dilute liquid in the separator to the top. The concentrated brine is pumped (6) through the heat exchanger (1) to waste. At the top of the column the ice comes in contact with the steam produced in the direct freezer and condenses the steam to fresh water. A very small quantity of this fresh water flows down the separator, counter current to the ice. The greater part is pumped (7) through the heat exchanger to fresh water storage.

The cost to produce fresh water from sea water and brackish water by this process has been estimated using the standard procedure of the Office of Saline Water. This office has reports on the economics of the system.




CLEAVER BROOKS CO.,
*Milwaukee, Wis., March 26, 1958.*

HOUSE OF REPRESENTATIVES, PUBLIC WORKS AND RESOURCES SUBCOMMITTEE OF THE COMMITTEE ON GOVERNMENT OPERATIONS,
*Washington, D. C.*

(Attention: Mr. Robert E. Jones, Member of Congress, chairman, Public Works and Resources Subcommittee.)

GENTLEMEN: We have studied your letter of February 21, and are pleased to give you our comments. We believe that your questions about saline water conversion pinpoint the most important aspects to a remarkable degree. The subject seems particularly timely to us, since we have just returned from a trip which included inspection of plants of a variety of designs and ages in water-short areas in the Middle East.

You requested information regarding our own research and development. Our activities cover a period of 17 years in the field of saline water conversion. We roughly classify this field as dealing with waters of over 3,500 parts per million, TDS.

We have always employed evaporating means for conversion, although our policy has never limited us to this, and we have always sought a better method regardless of the process it might be. To date, however, we have found no way to supplant evaporation, which we classify in three main types:

*1. Submerged tube*

There are some plants of this old and widely used design in operation on sea water which are among the most successful installations from a mechanical standpoint. We believe, however, that some basic limitations to this system have been indicated in sufficiently definite form to strongly suggest that the present trend to other types will continue.

*2. Vapor compression*

Where the raw water can be readily treated by softening, this is perhaps the most favorable method known today. It is usually used for sea-water-evaporating jobs which fall within these approximate limits:

(*a*) Relatively small plants, up to, say, 200,000 gallons per day.
(*b*) Fuel difficult to procure or relatively expensive.
(*c*) Good maintenance facilities available. Keeping in mind that this type is highly efficient and compact, it is ideal for many military uses, which are usually within the above limits.

This process has too many limitations to be considered for large-scale seawater plants now. Future improvements may make it far more favorable, if not one of the best ultimate answers. The low-energy requirement is attractive where primary energy must be used as compared with waste heat.

Although the first cost would be high, it is interesting to contemplate that by using enough heating surface and an efficient compressor, a machine using this process could be built today which would come closer to the theoretical 2.8 kilowatt-hours per 1,000 gallons of pure water from sea water than any other available process.

*3. Multistage flash*

In recent years our efforts in research, design, and manufacturing have been mainly concentrated on the low-temperature multistage flash evaporator for marine and land-based applications. We still offer vapor compression and submerged tube types, but the flash evaporator is more widely applicable for the following reasons given in their order of importance:

1. It operates substantially without scale. For normal sea water, no feed treatment is required if the "once through" type of principle is used, and temperatures kept low.
2. It is simple to operate and maintain. There are few controls and moving parts.
3. It can use a relatively low-level heat source.
4. First cost is favorable.

It follows that this type is a good choice when waste heat can be used, as for example from diesel engines. When combined with a powerplant, using steam from condensing-extraction turbines, the cost of water is estimated to be about 85 cents per 1,000 gallons.[1] While this cost is far from favorable for agricultural purposes, costs more than double this are now being tolerated for domestic and certain industrial uses, which is to say that this figure seems to at least be drawing somewhere near the target area.

Concerning your specific questions, our comments are as follows:

Question No. 1: The current state of progress (both here and abroad) in saline water conversion.

We believe that progress has been good with regard to plants for domestic and some industrial uses. During the past decade, the installed sea water distilling plant capacity throughout the world has grown substantially. In rough figures, from about 1 million gallons per day plant capacity in 1948 to about 12 million gallons per day, not including small plants below, say, 50,000 gallons per day.

There are many types of plants in operation all over the world. Often the design of a plant relates to the particular economic circumstances. In Kuwait, for example, fuel is substantially free, so that the plants are relatively simple and are not adaptable as such to other areas of the world where fuel is expensive.

Concerning the conversion of sea water for agricultural use, it is evident that the progress has been disappointing. There appears to be no factual evidence today which suggests surety that a price appreciably below $100 per acre-foot, if all costs are considered, will ever be attained.

Question No. 2: The extent of coordination between the Federal Government, private industry, and other public and private groups, both here and abroad.

We believe that the coordination between Federal Government and private industry could be substantially improved. The mechanism by which this could be better accomplished, however, is a subject for much more detailed discussion than seems warranted here. In general, however, more liaison at least is indicated. Among other advantages, improvement in this area would help to avoid expenditures of funds on schemes which may have already been tried or evaluated and found wanting in one respect or another.

Question No. 3: Whether the rate of progress ought to be accelerated either in basic research or in engineering applications of known processes,

[1] Based on firm quotations for 1¼ million gallons per day plant Also, fuel at 8.5 cents per gallon, 20-year amortization, 6½ percent interest. Where fuel is free, as with waste heat froom diesels, cost on same basis is about 35 cents per 1,000 gallons.

or both; and, if funds are limited, whether basic research or engineering applications should be emphasized.

We believe the problem of reducing costs of sea water conversion can be roughly divided in two parts. First of all, there is the matter of improving processes already in commercial use. A manufacturer does not always have funds available to try out all promising modifications or variations of existing processes. Also, a manufacturer does not have funds to set up a fairly large plant for demonstration and cost study at, say, some water-short seaboard community. The Federal Government could, perhaps, help in this respect, but we believe any work should be initiated through negotiation with manufacturers experienced in the field.

We believe the second part of the problem lies in basic research, and if funds are limited, we believe the Government should concentrate on this aspect.

Questions Nos. 4 and 5: Assuming progress should be hastened, what particular steps might be advantageously taken by the Government to encourage acceleration; and

Various processes under investigation and development, including, to the extent available, data on (*a*) conversion cost estimates, including all cost components on which the estimates are based; (*b*) quantity of water converted per day; and (*c*) source and salinity of water before and after treatment.

We believe these questions are partially answered in the above. We also think that the Office of Saline Water has done a creditable job in the field of basic research and in the investigation of processes not now in commercial use, taking into account the magnitude of the problem and the funds available. One of the most obvious methods of accelerating the program lies in the appropriation of additional funds.

Concerning cost estimates, conversion data, etc., there are, perhaps, many ways of attacking this problem. At the moment we rather favor the construction of a fairly large plant for demonstration. Perhaps, this should be along the lines of a design contest with manufacturers submitting their own ideas, guaranties, and firm prices for a plant of, say, 1 million gallons per day. All appropriate cost criteria, such as amortization, fuel cost, etc., to be stipulated by the Government.

We hope the above will be of help in your overall appraisal of the sea water conversion problem. We have enjoyed studying your questions and setting forth our comments. We will be pleased to cooperate with further information at your request.

Sincerely,

F. A. LOEBEL,
*Vice President.*

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SARASOTA, FLA., *March 1, 1958.*

Hon. ROBERT E. JONES, M. C.,
*Chairman, Public Works and Resources Subcommittee,*
*Congress of the United States, House of Representatives,*
*Washington, D. C.*

DEAR SIR: The enclosed reprint from the Quarterly of the American Interprofessional Institute presents a brief, nontechnical summary of the reasons why there is a saline water problem, and what methods are in use or have been proposed for desalting saline water.

Several enclosed typewritten sheets present further comments on various aspects of this subject, in the order suggested by your letter of February 21.

If I may do anything further to advance the work of your committee please let me know.

Sincerely,

HORACE G. DEMING.

PROGRESS AND PROSPECTS IN THE DEMINERALIZATION OF SALINE WATER

1. Important progress in the demineralization of saline water has been made the world over.

Purification of sea water by distillation has long been practiced by the navies of the world. Their equipment has recently been very significantly improved. At present, the domestic and industrial needs of whole communities in the Netherlands West Indies are being supplied by distillation of sea water.

The chief difficulty in the purification of water by distillation has been the accumulation of scale on the surfaces of the evaporator tubes. This evil may be greatly reduced by chemical pretreatment of the water to be distilled, or by "seeding" the partially concentrated liquid with material that causes the scale-forming impurities to separate within the body of the liquid as a finely crystalline slude, instead of being deposited upon and clinging to the heated metallic surfaces.

In the newly developed Hickman process for evaporation with vapor compression, the deposition of scale is delayed or prevented by carrying out the evaporation at a sufficiently low temperature, perhaps under 150° F. This is a significant achievement.

However, there is still much to be learned about the causes of scale formation and the best ways to deal with it. Fundamental research might reveal conditions or surfaces capable of completely suppressing scale. Such work is doubtless now being done in several laboratories. It may or may not be really fundamental, and nothing is known to the writer about the degree of correlation between the contributing laboratories.

The other chief method now in use for the demineralization of saline water expends electrical energy in propelling salt particles (ions) through membranes that prevent the passage of water. In this country the "membrane process" has been chiefly developed by Ionics, Inc., with the aid of the Office of Saline Water. Abroad, it has been independently developed in England, France, the Netherlands, and elsewhere. It is in operation, demineralizing brackish or slightly saline water, on a fairly large scale in several different plants set up by Ionics, Inc. In South Africa a large installation now successfully treats salt water pumped from the mines, rendering it fit for use in irrigation.

The process initially ran into difficulties from the deposition of scale on the membranes, the development of high electrical resistance, the failure of the membranes, high installation costs, high cost of repairs and replacements. These troubles have now largely been overcome, and the process is on a sound basis, with an assured future.

However, the membrane process will not at present desalt sea water, since the effectiveness of the membrane falls off rapidly as the concentration of dissolved salt increases. If the salt concentration is low, the cost of the electrical energy needed to purify water by this process is proportionately low. The cost of distilling water is, on the contrary, about the same for slightly brackish water as for sea water itself. The two processes are consequently not in competition except in intermediate ranges of concentration. At low concentrations the membrane process has an advantage, although it is not adapted for a very small installation, such as one supplying a hotel or a small factory.

Although the membrane process is in actual use in several different countries, the membranes are still expensive, only a few different types of membranes have been used, and a good many fundamental questions concerning them have still to be answered. More will be said in what follows about these fundamental questions.

The energy of sunlight has been used in small-scale distillation in many different localities where the sunlight is intense and the rainfall scanty. About 440 calories of solar energy fall on each square centimeter of the earth's surface during an average day in the latitude of central Florida. If this were applied in distillation without loss, though without recovery of heat in condensation, a square yard of horizontal surface would produce nearly 2 gallons of distilled water in an average day (most of the yield being in the winter months). In the Virgin Islands, solar stills have given about a third of the theoretical yield, or about 0.7 gallons of distilled water per square yard per day, recalculated for the latitude of Florida.

Because solar stills are useful in isolated or desert locations, where electrical energy is expensive or unavailable, further work on their improvement is warranted. Any radical new design, with heat recovery during condensation, might easily double the yield thus far obtained. Furthermore, it seems likely that important progress will soon be made with the problem of converting solar energy into electrical energy. Then both the other processes that have been discussed will begin to be important in regions having abundant sunlight.

Many other processes have been proposed for desalting saline water, and the most promising of them have been actively studied. The only one in actual use in anything other than a laboratory scale is purification by ion-exchange resins. This process is limited to the production for medicinal or laboratory use of the

equivalent of distilled water, from water that originally was nearly free from salt. Saline waters containing more than about 2,000 parts per million of dissolved salts cannot be economically treated by the ion-exchange method, because the cost of regenerating the resins with acid and alkali becomes prohibitive when regeneration is frequent.

2. The symposium on saline water, held in Washington early in last November, was an excellent opportunity for workers in this field to become acquainted with this work of others, all over the world. We all felt that this effort toward coordination was very much worthwhile, and greatly to the credit of the Office of Saline Water. Another symposium should be held.

It seems not to be generally realized that there is no "best method" for the treatment of saline water. Manufacturers who have advertised that they have already solved this problem are just pretentious. There is some duplication of effort and overlapping of work done in different laboratories in industry and between different administrations in the Government. This can be reduced by prompt and continuous exchange of information. We suggest the creation of a reference and reading room, in one of the scientific libraries of Washington, where readers may quickly acquaint themselves with the very latest aspects of work on saline water.

3. A new process for treating saline water first needs to be shown to rest on sound principles. It is then quickly taken up by private industry if it promises to be economical. The Government should therfore subsidize basic research, rather than engineering development. Nevertheless, when a process has been developed to a point where a particular branch of the Government, the Navy for example, has prospects of using it, one may justify the expenditure of public funds in engineering studies.

4. New ideas are quite rare. The men who produce them are not always to be found in the best-equipped and most famous laboratories. About all the Government can do to increase the supply of really novel suggestions is to make generally known the existence and importance of a saline water problem, and supply information about the methods that have already been proposed or applied in dealing with saline water. A good proportion of the suggestions that come in will not bear mathematical examination, based on known scientific principles. Others can easily be shown to be prohibitively costly. The few that pass both these tests should be vigorously pushed and brought to trial without delay. At the symposium in Washington, one committee chairman was heard to say that there is too much delay in getting Government support for new ideas that can easily be shown to be worthy of support.

5. It has been mentioned that the membranes now in use are of very limited range of chemical types. The work of this consultant's laboratory has been an attempt to extend this range, to produce, for example, much cheaper membranes. This effort has been of limited success, not because the problem lacks promise, but rather because a small laboratory encounters inteminable delays in getting materials and equipment, in finding qualified help, and even in getting answers to letters. This consultant therefore hopes presently to become a member of a larger group, organized to deal with fundamental problems, and closely coordinated.

Starting with work done in this laboratory, it may presently be possible to extend the use of membranes to much more highly saline waters than those now treated by this method. There is also a whole new field in prospect, almost completely unexplored. This concerns the use of membranes of exactly the opposite type to those now in use. Instead of driving the ions of a salt by electrical pressure, through membranes that prevent the passage of water, one may evidently drive water by mechanical or centrifugal pressure, through membranes that prevent the passage of salt. Experiments at the University of Florida are a start in this direction. There is no doubt that chemists can solve the problem of creating good membranes of this type. In this consultants' laboratory some of them have already been tested. We have already carried through a mathematical analysis that gives the essential specifications of membranes that will work. If such membranes can actually be created there are several totally different new methods for demineralizing saline water, easily to be tested, and not depending on a supply of electrical energy.

Beyond all this lies the fundemental study of the manner in which marine organisms accumulate nearly fresh water, though they live in a salt-laden environment. There would seem to be no prospect of growing fish or seaweed, for example, as a practical device for purifying water on a large scale. Yet

if some individual, more ingenious or better prepared than anyone so far, should come up with a method by which one may imitate natures processes in the laboratory or factory, the proposal should be given very earnest consideration.

Finally, the problem of saline water should be kept in constant contact with the latest proposals for winning energy cheaply from the sunlight. Any new development in that field would make methods for desalting water important which now cost far too much to consider.

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[The Quarterly of the American Interprofessional Institute, Vol. 32, No. 1, Fall 1957]

## The Problem of Saline Water

Horace G. Deming,[1] Consulting Chemist, Sarasota, Fla.

The problem of saline water lends hardly a glance at the problem of winning irrigation water from the ocean. If the ocean were as free from salt as any fresh-water lake, the cost of pumping it into city mains, just a few miles away might be too great to be considered. The cost of pumping it to the top of neighboring hills or to the upper reaches of valleys, within sight of the ocean, would be too great for most kinds of crops. We are defeated by the habit of water always to run down hill, and by the present high cost of energy.

Petroleum products and natural gas, as everyone knows, are pumped through pipelines, halfway across a continent. Yet this is possible only because they are worth, gallon for gallon or pound for pound, about 600 to 1,000 times as much as city water, and about 1,500 times as much as delivered irrigation water.

So the ocean is likely to remain as the ages have made it. Year by year it grows just a little bit saltier, as perhaps a hundred million tons of salts each year are leached by earth's rivers from the rocks and soils and carried to the sea. The oceans contain dissolved salts that would make about 4½ million cubic miles of solid salt. That is something like the total bulk of all the continents, above sea level. Yet the ocean has dissolved all this and is still far from saturated.

Most of the present land areas of the earth were beneath the sea in ages past, and were repeatedly submerged. So the less soluble of the ocean's salts have been laid down over all the continents—layers of limestone and gypsum that are often miles deep, and mountain ranges of dolomite. Even the more soluble salts (those of sodium, magnesium, and potassium) have been accumulated in inexhaustible solid deposits when prehistoric seas, cut off from the main body of the ocean, repeatedly were flooded and repeatedly evaporated in shallow basins.

So a part of the problem of saline water is the problem of preventing the encroachment of salt into fresh water in the areas now far from the ocean. In many of our American States, from Pennsylvania, Ohio, and Michigan to Texas, Arizona and Utah, supplies of fresh water are being ruined by salt that was left behind by the oceans of long ago.

The problem is to protect and conserve. As with other natural resources, we must make sure that what we have is not destroyed by the unrestrained activities of man.

The Clifton Hot Springs in Arizona dump 25 to 70 tons of salt every day into a small stream, which in turn seriously contaminates the Gila River. There are some other instances in which underground waters come in contact with deposits of solid salt, then issue to the surface as river-spoiling salt springs. Nevertheless, most of the destruction of fresh water resources is the work of man.

The production of table salt and of alkali and chlorine from the salt deposits of eastern Ohio and neighboring States yield salty residues that have been dumped into rivers. Salt carried by these invades wells and ruins city water supplies downstream for a hundred miles. Oil wells frequently bring to the surface vast quantities of salt water, which is often discharged into rivers or carelessly impounded. Wells drilled for fresh water may strike salt, then just be abandoned, to contaminate neighboring water supplies, instead of being sealed off.

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[1] Dr. Deming, currently a member at large, was a member of the Lincoln chapter for many years. As described in this article, his present work has contributed some new membranes and new methods for using membranes for the purification of water.

Canals near low-lying coasts may be deepened until they are invaded by salt water, which then ruins a water supply and may compel a neighboring city to seek a new supply at an expense of a million dollars. Even irrigation projects may ruin lands which they seek to reclaim, as salts leached by irrigation from the upper reaches of a valley accumulate in soils that are farther downstream. Laws are being passed, everywhere, to put an end to all these bad practices. The pity is that in the conservation of natural resources no law can be made retroactive. When salt has once invaded a fresh water source it stays there for many decades. Men may destroy in a hurry, but nature repairs at leisure.

Nature, however, long ago did her best to ruin vast areas of the earth, without sensing that these would some day be needed to support an upsurging population of what we take to the nature's most admirable creation, man. Mountains were pushed up in needless places, denying rainfall to millions of square miles of neighboring lands. In our Far Western States the plains were rent by fissures, hundreds of miles long, which permitted great fault blocks to be uplifted and interposed between flowing rivers and the sea. From that moment all the salt that would otherwise have been discarded into the ocean was left to accumulate in the soil, in low-lying places. So we have a Great Salt Lake, also a Searles Lake and a Death Valley (both full of borax and alkali), and thousands of ponds and lakes and marshes, loaded with alkali and salt.

Meanwhile, during many recent centuries, the level of the ocean has steadily risen, as glaciers and polar ice have slowly melted. Since 1930 its level has risen about 6 inches along our Atlantic and gulf coasts. In many places, fresh water wells are now definitely more saline from this cause.

So the problem of saline water is not merely one of conserving existing fresh-water supplies. It also concerns desalting water which in some way has become just a little bit salty. Supplies for domestic use should not contain over 500 parts of common salt in a million. That is about an ounce of salt in 15 gallons. Water that has over twice that amount of dissolved solids is regarded as saline or brackish, or may be alkaline (usually from sodium carbonate or bicarbonate). It alters the structure and growth habits of plants and limits their capacity to use water. Certain dissolved salts (bicarbonates, borates, salts of lithium and barium, etc.) may be definitely toxic. Most crops will not tolerate saline or brackish water, though tolerance is improved where good drainage provides for the continuous removal of salts from the soil. The ocean contains about 35,000 parts of dissolved salts in a million of water, which is a pound of salts in a little over 3 gallons. About three-fourths of this is common salt.

The sun evaporates from the oceans about 80,000 cubic miles of water every year, and about a fifth of that amount is provided in addition by evaporation from lakes and rivers. The total evaporation is balanced by reprecipitation, chiefly as rain or snow; but only a fourth of this falls on the land, and most of it in the wrong places. The best answer to the problem of saline water would be to insure that the wind should no longer blow where it listeth, but should be controlled to deliver abundant rains, alike to the just and unjust, in all of earth's populous places.

The second best answer, and the one that may finally be attained, would be to use the sun's energy, or the energy of atoms in nuclear fusion, to free saline waters from salt. Heat is needed to vaporize liquid water; and every schoolboy knows that this heat is set free again when the vapor is recondensed into liquid. So readers who are not only awake at this point but alert and attentive will suggest that we use the heat set free in recondensation to evaporate a second quantity of water; and the heat obtained in recondensing this to evaporate a third quantity.

Thus the energy needed to free saline water from salt might conceivably be reduced to zero. We are reminded of the stock prospectus of an alligator farm in Florida, which pretends to feed the small gators exclusively on the carcasses of their grandparents, slaughtered for their hides. A combined nursery and old folks' home is thus made to pay a profit. The only expense is taxes. It is precisely by recovering the heat set free in recondensation, then using this in evaporation, that engineers have greatly reduced the cost of distillation. Their devices have been classified as multiple effect evaporation, flash evaporation, and distillation with vapor compression. Yet the cost of energy can never be reduced to zero, even were there no heat loss. This is because the heat expended in evaporation, whenever water is salty, is always a trifle greater than the heat recovered in the subsequent recondensation of the water vapor.

Expressed in another way, when salt water is evaporated at any temperature, the pressure that the vapor exerts is always a trifle less than it must be to be able to recondense to liquid at that temperature. So, whenever water is salty, we must not only evaporate, we must cool or slightly compress the vapor. Then recondensation takes place, heat is recovered, and the only cost for energy (except for slight losses of heat) is for energy spent in the compression of the vapor.

Calculation shows that the inescapable minimum in an infinitely slow operation is about 2.8 kilowatt-hours of energy for the distillation of 1,000 gallons of sea water. Proportionately less energy would be needed for waters that are less saline. The best than can be hoped for is to expend at least 10 times the theoretical least energy for a water of a specified salinity. There are of course other costs, in labor, depreciation, interest, repairs, and so forth.

Distillation with vapor compression has made great strides during the past few years. In the Badger-Hickman still, described in recent technical magazines,[1 2 3] evaporation is at 125° to 150° F., from the concave surface of shallow pans, several feet in diameter. The pans are assembled in pairs, face to face, like the pleats of an accordion, on a rotating horizontal or vertical shaft, within a cylindrical container. They rotate at a speed sufficient to spread the incoming saline water in a uniform thin film over the concave surface from which it evaporates. At the outer margin of the rotating concaves surface the liquid residue that has been concentrated by evaporation is collected and carried away to discard. The vapor, after being slightly compressed by a centrifugal pump, passes over the convex outer surface of the rotating pans, where it condenses, liberating heat. The condensate in flung off the outer rim by centrifugal force, and is passed through a heat exchanger, where it is cooled, transferring heat to an incoming stream of saline water.

Stills of this type have been greatly improved during the past 3 years. The most recent one gives a salt-free distillate, without production of scale, at an expenditure of 42 kilowatt-hour of energy for 1,000 gallons of distillate. This is about 15 times the theoretical least energy requirement. Small household stills, using this principle, may be on the market within a few years. A large installation is about to be put into operation to distill sea water on beach near Wilmington, N. C.

Thousands of small stills of different types have been built for the United States Navy. A still on the *Nautilus* is believed to be the first to be operated on nuclear power. In the Dutch West Indies (Aruba and Curacao) new multiple-effect evaporation plants will soon produce as much as 10 million gallons of distilled water a day from sea water. Evaporation by the heat of the sun is being used in hundreds of widely scattered small plants in Australia, Algeria, the Near East, California, Arizona, and Florida. Cost of installation is several dollars a square foot. In the Southern States just mentioned the year-round distillation rate may be as much as 0.7 gallon per square foot per day, though most of this is during the summer months.

Many other schemes for desalting water have been proposed or are being actively studied. We may disregard "treatment with chemicals," since when domestic water sells for about 30 cents per thousand gallons the cheapest known reagents (slaked lime and sulfuric acid, for example) are far too expensive to be used just once and then discarded. Purification by ion-exchange resins is useful for softening domestic water or for preparing the equivalent of distilled water in the laboratory or in medicinal preparations. For municipal use or for irrigation it is quite out of the question, since the expensive resins, when "exhausted," must be "regenerated" by chemical treatment.

There is some promise in freezing water, to separate it from salt, for even sea water freezes out, nearly fresh, when proper precautions are observed. Electrolysis (separation by passage of an electric current) is far too expensive, even when marketable byproducts (chlorine and caustic soda) are obtained.

It will be interesting to consider what must actually be done, in the simplest imaginable procedure, to separate water from salt. The salt, whether solid or dissolved, exists as minute particles called ions, of far less than microscopic size. Some of these carry positive and others negative charges of electricity. In

[1] Hickman, Centrifugal Boiler Compression Still, Industrial and Engineering Chemistry, 49, 786–800 (May 1957).
[2] Jenkins, Fresh Water From Salt, Scientific American, 196, 37–45 (March 1957).
[3] Jenkins, Conversion of Saline Waters. In "Water," the Yearbook of Agriculture, United States Department of Agriculture, 1955.

common salt there are equal numbers of positively charged sodium ions. Na+, and negatively charged chloride ions, Cl—. In a solution of salt in water the salt ions are scattered nearly but not quite uniformly among the water molecules. So the simplest imaginable procedure to separate water from salt is to contrive in some way to push the water molecules in one direction and the salt ions in the other (or to do both these things at once) until we get a separation. This is just what we would have to do in separating a flock of sheep (water molecules) from a few intermingled goats (salt ions).

When we deal with salts, however, we meet the difficulty that their ions (the goats of our analogy) are of two kinds, oppositely charged. If we apply an electric force to drive the positively charged ions in one direction, the negatively charged ones will be driven in the opposite direction. The middle part of the solution will eventually be cleared of both kinds of ion, but the cost of the electrical energy will be prohibitive. We need some method which will isolate a great many distinct regions within the solution, from all of which both kinds of ions may be cleared at once, without expending much more energy than would be needed for a single middle region.

The way to do this is to interpose across the solution a number of barriers, through which one sort of ions will pass freely, whereas the other sort is blocked. If the barriers are all of the same kind they may, for example, block the ions that are moving toward the right, and pass those that are moving toward the left. The result is to create at the right of every barrier a region from which both kinds of ions are removed, and at the left of every barrier a region into which both kinds are accumulated. These enriched and depleted regions may be separately and continuously drained away. Another plan is to have barriers that are of two kinds, which alternately block the left-moving and the right-moving ions.

Barriers of this sort, which will freely pass either positive or negative ions, but which will almost completely block ions of the opposite type, have been known for about 10 years. They are called ion-selective or permselective membranes. Under grants from the Office of Saline Water, United States Department of the Interior, tests were made, several years ago, by Ionics, Inc., on saline waters in Oklahoma and South Dakota, with a mobile plant, mounted on a trailer truck. The electrical force applied is from a 500-volt, direct-current generator. The membranes of alternating character are assembled in a stack of several hundred membranes, with intervening films of flowing water. This experimental plant is now being operated in Denver. Working installations are in Israel, Hawaii, and elsewhere.

Meanwhile, the membrane process has been independently developed in Britain, the Netherlands, France, South Africa, and elsewhere. In South Africa a plant with the capacity of 3 million gallons a day is planned for desalting water pumped from mines, making it available for irrigation. By thus serving a double purpose, the process tolerates a cost which is said to be about 30 cents for 1,000 gallons.[4]

To separate water from salt, it will also serve to immobilize both the oppositely charged kinds of ions at an interposed membrane, while water molecules are driven past them in either direction. This is filtration, but of a very special kind, since no ordinary filter is tight enough to hold back ions, and at the same time open enough to pass water molecules. This method, and a combination of this with the preceding method, are being actively studied, under grants from the Office of Saline Water.

So, by considering the simplest imaginable procedure to separate water from salt we have come back to a method foreshadowed by Francis Bacon, over three centuries ago, in his New Atlantis (1627) when he spoke of "pools, of which some do strain fresh water out of salt." The problem is more difficult than could have been imagined in Bacon's day, since the very properties that make water useful make it hard to purify. Water is useful because it is a liquid, rather than a gas; because it penetrates into and interacts with living tissues to make possible the processes of life; and because it dissolves salts and nutrients and thus serves as the vehicle of life in the blood stream, in digestion, and the liquid

[4] To be published: Symposium on Saline Water Conservation, Washington, D. C., November 4–6, 1957. The National Academy of Science, Washington, D. C.

contents of every living cell. There is nothing at all like it in all the realm of chemistry.

The unique properties of water depend on the fact that its molecules are chemically active. They not only combine with molecules of other things but even with one another. They cling to the ions of a dissolved salt to form water-encumbered hydrated ions; and they cling to one another to form entangling networks, through which hydrated ions can be propelled only by tearing the networks asunder, as in propelling a barnacle-encrusted ship through a mass of tangled and interlaced seaweed. That is why considerable energy still needs to be expended in our simplest conceivable procedures for purifying water.

If water molecules did not have this habit of clinging so tenaciously to other molecules and to one another, it would be easy to push salt ions past water molecules, or the reverse, and get a separation. But water would not then dissolve salt, so the problem would not exist. Water would not even be a liquid, but a gas, like hydrogen sulfide. It would be of little interest to us, and life on this planet, if it existed at all, might be based on ethyl alcohol, to the delight of a part of humanity. Water is hard to win because of the very properties that make it worth winning. May not the same be true of most of life's blessings?

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E. I. DU PONT DE NEMOURS & CO., INC.,
*Wilmington, Del., March 4, 1958.*

HON. ROBERT E. JONES,
*Member of Congress, Chairman, Public Works and Resources Subcommittee, Congress of the United States, Washington, D. C.*

DEAR SIR: In reply to your letter of February 21, our interest in the program of water conversion has been limited to a modest examination of experimental, weather-resistant plastic films which might find application in solar saline-water distillation. Our interest has been to characterize the requirements of these plastic materials for this and other outdoor uses.

Our examination has included tests with three small, inflated plastic solar stills which were capable of producing from a few quarts to 5 gallons of fresh water daily. We have also supplied small test quantities of plastic materials to others, and made preliminary evaluations of our products in this service.

At present our experimental work is limited to the continuation of exposure tests on plastic films. Abroad, we have offered test quantities of these films for solar-energy research, which would include small solar stills.

We have informed the Office of Saline Water concerning the results of this work; and have offered the Office and its contractors quantities of our plastic materials in connection with their interests in this subject.

We are not acquainted with any survey of the gross present or future water needs, or the market value of water from conversion equipment. A satisfactory rate of progress and area of emphasis would appear to be related to these factors.

Our plastic films appear to be resistant to weathering, although subject to mechanical damage. An inflated plastic film which covers a solar still has been satisfactory for the past year, indicating that air inflation has some promise for mechanical support. The production of fresh water from these stills has been somewhat less per day than has been reported by others. It is probable that some improvement in productivity would be realized from a study of still design.

Our very high spot evaluations indicate that the prospective full cost of water, including amortization of the investment, could range upward of $1 per thousand gallons of fresh water produced from a solar still with favorable conditions. There has not been constructed here or abroad, to our knowledge, a solar still of sufficient size to afford an accurate appraisal of this process as a means for water conversion.

The economics of solar distillation, under favorable circumstances, at present probably would not exclude it from a competitive position with respect to the reported costs for other conversion methods.

Yours very truly,

ENGINEERING SERVICE DIVISION,
FRANK E. EDLIN.

FLAKICE CORP.,
*Brooklyn, N. Y., March 13, 1958.*

HON. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee, of the Committee on Government Operations, House Office Building, Washington, D. C.*

DEAR MR. JONES: 1. Due to my absence from the office, response to your letter of February 21, 1958, has been unduly delayed for which please accept my apologies.

2. We have a long history in connection with the freezing of salt water, but were I to forward you our reports, some of them abstracted and published, I fear I would be departing from the objective of your letter. I shall content myself, therefore, with a brief history of our work.

3. From 1931 until 1938 we endeavored to exploit eutectic salt ice, which is the freezing of 23.3 sodium chloride and 76.7 water by weight, putting up a commercial sized plant therefor and selling and using quantities of the ice in the transportation of perishables in railroad cars, truck, etc., at temperatures between 0° F. and +10° F.

4. Since that time we have done a large amount of experimental and development work in the freezing of sea water and less than eutectic concentrations of salt ice and its application to the preservation of perishables, particularly fish, between 26° F. and 32° F.

5. Apparently we are the only people who know how to make ice from salt water, which ice has exactly the same salt content as the water from which it is frozen when concentrations are less than the eutectic. In this work, of course, we have learned a great deal about the freezing into ice uniformly of salt and also the freezing out of salt. We have also done some preliminary work on the concentration of sugars and salts by freezing and then pressing and have developed a machine called an "extruder" for the pressing. Our preliminary work on this machine indicates that one of our processes will produce potable water (500 parts per million of salts) from sea water.

6. As we are a small company without appreciable financial resources, we have been unable to afford the luxury of obtaining grants from the Government for our work in competition with the larger companies, who appear to be amply able to devote their time and attention to the time consuming negotiations with Government. We are now building some salt ice-freezing plants of large size. Upon the completion of these, we shall endeavor to devote some of our profits therefrom into the perfection of our process for desalting sea water. We are fearful that the large amount of energy diversion that would be required to do this under any Government grant or auspices would be a threat to our survival and we must, therefore, proceed in our own slow way. This method has in the past produced results in the long run ahead of other methods.

7. With reference to your specific paragraphs, I can only most humbly suggest the following:

(*a*) Your paragraph 1: The current state of progress. Insofar as I can ascertain from my limited source of information from our associates here and abroad, the United States is in advance of the current state of progress in saline water conversion.

(*b*) Your paragraph 2: The Federal Government is doing an excellent job of cooperation with the larger corporations of private industries and the universities, but so far no method has been found that would permit the skill wrapped up in some of our smaller companies to be made available to the Government.

(*c*) Your paragraph 3: Both, as funds are limited, engineering applications should be emphasized.

(*d*) Your paragraph 4: Steps whereby some of the smaller companies could afford to undertake research for the Government.

(*e*) Your paragraph 5: I believe has been answered in the foregoing.

8. Thanking you for your letter and the opportunity to make this rather feeble response, I remain

Sincerely yours,

CROSBY FIELD, *President.*

THE FLUOR CORP., LTD.,
*Los Angeles, Calif., March 25, 1958.*

Hon. ROBERT E. JONES,
*The Public Works and Resources Subcommittee of the Committee on Government Operations, House of Representatives, Washington, D. C.*

DEAR SIR: Pursuant to your request of February 20, we are pleased to forward our information and comments on the activities being conducted under the sponsorship of the Office of Saline Water, Department of the Interior.

We should like to preface our remarks with some general observations on the Office of Saline Water activities. We believe that the investigations sponsored over the past several years have resulted in a considerably improved understanding of the technology and economics associated with the development of supplemental water supplies from saline sources. While there is still opportunity for considerable improvement to be made, it appears that the currently available technology has brought commercial application of recovery processes nearly to the realm of economic feasibility. This is particularly true of the distillation processes as applied to sea water.

The economic attractiveness of any currently available or even proposed scheme depends to a larger degree upon the methods of cost evaluation. The Office of Saline Water has contributed to the standardization of cost methods which has aided in making better comparisons of various conversion processes, using common denominators. This procedure is fully described in A Standardized Procedure for Estimating Cost of Saline Water Conversion, Office of Saline Water, March 1956. On the contrary, great confusion still exists in the costs of water obtained from natural sources. Subsidies, bond issues, taxes, and various practices of determining water rates (e. g., rates based on number and types of plumbing fixtures in lieu of meters and even where meters are in use, there is considerable variation in actual practice in the determination of minimum charges and in the use of step or block rates for varying amounts of water consumption) all cloud the issue of the real cost of natural water.

In many instances, special groups (for example, agricultural) obtain water at considerably less than the total real cost. Other consumers pay the difference. An example of such economic anomalies is afforded by examination of the financing of the Metropolitan Water District of Southern California. According to J. W. Milliman (California Agriculture, vol. 12, January 1958, and private communications), the city of Los Angeles has purchased a total of $3,015,778 of MWD water during the period 1941–56. Since 1929, taxes for the project have been paid by the citizens living within the city of Los Angeles. They have paid $144,735,913 in direct taxes during the period 1929–56 (approximately $111 million being paid 1941–56). The citizens of Los Angeles, who thus have paid approximately $1,200 per acre-foot for water used, have been subsidizing other users of MWD water. In 15 years of operation of the MWD (1941–56), the total cost for water delivered, not including bond amortization charges, amounted to $65.32 per acre-foot. Such cost figures are in strong contrast to the many glib statements in the press and elsewhere about natural water at a price of as little as $5 per acre-foot.

In contrast to the above, saline water conversion costs as currently reported from the Office of Saline Water are all based on sound economic evaluations which include all factors that make up the total cost. For this reason, such costs cannot be reasonably compared with quoted prices for obtaining supplemental water from natural sources. The applicability of saline water conversion processes in any specific instance, therefore, should be compared with alternate methods of obtaining additional water but on a common cost evaluation method.

In order to answer the particular points which you set forth in your letter of February 20, we shall refer our remarks to the numbered paragraphs. We would like to point out, however, that inasmuch as our activities have been concerned almost exclusively with the investigation of evaporative sea water conversion processes, we will limit our remarks largely to this area.

(1) With regard to current state of progress in saline water conversion to the present time, the majority of sea water conversion processes that have been demonstrated commercially are distillation processes. Other than ship-

board installations, most of these to our knowledge have been integrated with power generation facilities and, therefore, have been dependent upon turbine bleed steam as a source of evaporative heat. However, it does appear that there has been sufficient reduction to practice by this distillation method that at least in specific instances the production of potable water from the sea through such a medium is economically attractive. We believe that distillation processes will continue to be the preferred route for some time to come by localities that find they must obtain supplemental water.

We are aware of the pilot plant work being sponsored by the Office of Saline Water in the study of several distillation process schemes. These, of course, include vapor compression (Badger-Hickman system) and various combinations of long tube vertical or submerged tube evaporators and multiple-flash units. All of this experimental and pilot plant work is leading to improvement in the art. The results of such work, coupled with the commercial applications, ought to lead to realistic design of practical large-scale commercial units.

A very important facet of any conversion system is the vast consumption of energy required for operation. This not only applies to saline water conversion operations, but also to acquisition of additional natural water supplies where any appreciable amount of pumping is required. Utilization of exhaust steam from electric powerplants can supply some of the energy but probably would only satisfy a small part of our future water requirements. A good example of the use of powerplant exhaust steam in saline water conversion is afforded by the plant now being constructed on the island of Aruba by our affiliate company, Singmaster & Breyer. Arid islands are ideally suited for such a combination and certainly such supplemental water for our own cities can be produced in this manner.

To supply major areas with converted sea water, the energy requirements are so large as to make it doubtful that economical use can be made of fossil fuels. The alternate energy source is nuclear fission. The use of nuclear energy in this application avoids, to a large extent, the transportation cost associated with the furnishing of large quantities of fossil fuels to a particular plant installation. In addition, the supply of such energy is almost unlimited in the foreseeable future and, therefore, permits the conservation of the fossil fuels for chemical manufacture or domestic fuel supplies. We are quite convinced, therefore, that before the large commercial conversion processes will become economically attractive, it will be necessary to utilize nuclear energy.

(2) Government groups at all levels have been quite cooperative with us in discussing the water problems. The Office of Saline Water has been especially helpful. Coordination between Federal and State and local governments has not been as effective as it might be. The primary reason for the latter appears to be lack of funds, particularly in the hands of the Office of Saline Water. The Federal group seems to be the logical choice to act as coordinator of national water problems. Greater availability of funds would improve the execution of the function.

(3) Whether or not the rate of progress ought to be accelerated depends to a large extent on the forecasts of future domestic water requirements, consistent with the economic utilization of our natural resources. We do not know of an adequate study that has been made on this subject and feel that funds should be made available for such an undertaking.

(4) More money should be expended on basic research in studying problems of scale control, materials of construction, and equipment design. Also, some money should be spent continuously for the exploration of new approaches to the saline water conversion process. Only by continuing to support such activities can it be expected that perhaps a technological break might be achieved which would have a major impact on the problems. At the same time, continued engineering application studies should be conducted, particularly with regard to the feasibility of using currently available techniques in actual commercial installations.

If, in a particular domestic locality, such engineering studies indicate that water from such a commercial installation could be attractive economically (at whatever the estimated real cost of such water may be), then it would appear in order to build a commercial prototype or demonstration plant. The operation of such a plant would permit the accumulation of long-term, realistic cost infor-

mation and would aid in pointing up the needs for additional research in the solution of operating and equipment problems. At the same time, it should be recognized that if such water could not be used economically, the mere construction and operation of a commercial plant certainly is not going to make the cost of the water any more attractive. In the latter instance, therefore, the equivalent amount of money might better be spent in further research, development, and engineering studies.

(5) As we pointed out earlier, we feel that our comments on processes under investigation should be limited to the area with which we are particularly familiar, namely, sea water distillation processes.

(5) (*a*) The attached table is a copy from our final report to the Office of Saline Water (Fluor Report RDR 1687). As can be seen, for the larger plant, the cost of water, depending on the method of financing, will vary between 50 and 65 cents per thousand gallons ($163 to $212 per acre-foot). The use of less expensive materials of construction might reduce these costs to the range of 40 to 45 cents per thousand gallons ($131 to $147 per acre-foot). Since our complete reports are available to the committee through the Office of Saline Water, we shall not make any further reproduction of them here.

(5) (*b*) Our studies examined various combinations of nuclear reactors and distillation processes in the 10- to 50-million-gallon-per-day range (10,000 to 50,000 acre-feet per year).

(5) (*c*) The source of water in all cases was assumed to be full-density sea water, 35,000 parts per million total solids, with a potable water production of less than 100 parts per million total solids.

We trust the above will be of aid to the committee in its investigations. We shall be pleased to answer any further specific inquiries at your request.

Very truly yours,

C. L. BLOHM, *Manager of Research.*

TABLE 18.—*Water costs for combination long tube vertical-flash evaporators with the suggested revisions*

| Capacity | 10,000,000 gallons per day | | 50,000,000 gallons per day | |
|---|---|---|---|---|
| Financing | Saline [1] | Government [2] | Saline [1] | Government [2] |
| Total investment [3] | $9,990,000 | $9,990,000 | $49,950,000 | $49,950,000 |
| Operating costs | Dollars per stream day | | | |
| 1. Fuel | none | none | none | none |
| 2. Electric power | 114 | 114 | 570 | 570 |
| 3. Steam [4] | 3,870 | 3,040 | 12,750 | 11,260 |
| 4. Raw materials | 273 | 273 | 1,365 | 1,365 |
| 5. Supplies and maintenance materials | 150 | 150 | 749 | 749 |
| 6 to 9. Labor [5] | 1,045 | 1,045 | 2,214 | 2,214 |
| 10. Amortization | 2,235 | 2,065 | 11,200 | 10,330 |
| 11. Taxes and insurance [6] | 599 | none | 2,995 | none |
| 12. Interest on working capital | 60 | 48 | 224 | 192 |
| Total operating cost | 8,346 | 6,735 | 31,067 | 26,680 |
| Cents per thousand gallons | 83.5 | 67.4 | 62.1 | 53.4 |

[1] Uses interest rates at 4 percent from saline procedure.
[2] Uses Government bonds at 2¼ percent interest.
[3] Includes 45 percent erection and assembly on long tube vertical evaporators and heat exchangers, and 30 percent on flash.
[4] Uses steam costs from table 11.
[5] Uses labor costs from table 16.
[6] Assuming no taxes and insurance for Government-financed plant.

NOTE.—By saline procedure from table 7, cents per thousand gallons 108.3 for both 10,000,000 and 50,000,000 gallons per day.

GULF RESEARCH & DEVELOPMENT CO.,
*Pittsburgh, Pa., February 27, 1958.*

HON. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee, Committee on Government Operations, House Office Building, Washington, D. C.*

DEAR SIR: Thank you for your letter of February 12 requesting certain information and opinions on the saline water conversion program of the United States Department of the Interior. I am pleased to answer your request. The following is based on my own views and those of the majority of the committee on membrane processes, which convened during the saline water conversion symposium held in Washington, D. C. I am not acting as an official spokesman for my company.

Under the leadership of Mr. David S. Jenkins, the Office of Saline Water has made a major contribution to the solution of the age-old problem of making fresh water from salt water. The basic principles used in the processes studied were well known before the Office was formed, but the program has greatly stimulated the development of these processes as well as basic research for their future growth. Moreover, it has served as an international clearinghouse of information on this subject, enabling workers in the field to utilize other people's advances much sooner than before. It has also worked out a uniform schedule for computing the cost of desalting processes, so that the economics of different methods can be compared without bias.

Of a greater number of feasible processes, three were selected for more intensive development; viz, (*a*) distillation (including solar distillation), (*b*) freezing, and (*c*) electrodialysis. All of them can handle both sea water and brackish (less saline) water, but the major potential of method (*c*) is in the field of brackish water desalting. Through recent technical advances resulting both from research sponsored by the Office of Saline Water and by others, it has been possible to improve these processes to the point where treatment costs of 50 cents to $2 per 1,000 gallons seem reasonable. These figures refer to large plants and represent extrapolations from pilot tests on a much smaller scale. They are, therefore, somewhat speculative. Moreover, they depend to a large extent on local factors. For instance, where turbine exhaust steam from powerplants is available, lower costs are possible.

While the treatment costs quoted above will usually not permit economic treatment of irrigation water, industrial and municipal use is not ruled out. This may lead to new patterns of settlement and additional practical living space in a number of areas of the United States and the world. A systematic survey of these possibilities in the light of recent improvements of desalting processes is not yet available.

It is important to encourage also work on methods different from the three mentioned above. While the larger portion of the funds of the program was spent for these three processes, radically new approaches have also been supported. It is desirable to continue this policy.

Coordination and cooperation with industry in the United States and with certain programs sponsored by foreign governments has been most satisfactory, but much remains to be done in establishing coordination with private groups abroad. It is realized that much valuable research and development is being carried out by foreign groups. For several countries, the salt water conversion problem is more pressing than for the United States and more emphasis is placed on it within the framework of the general research efforts of these countries. Many of these efforts could be stimulated and their results utilized also in the United States if the Office applied the present statute authorizing the spending abroad of up to 10 percent of the research funds. This could be done by applying, as much as possible, the same procedures and criteria for worthwhile projects as in the Office's past dealings with groups in the United States.

The rate of progress could be accelerated by the establishment and operation of larger pilot plants from which more realistic cost estimates could be derived. In addition, vigorous support for theoretical studies and fundamentally new ideas is urged. There is practically unanimous agreement among workers and administrators in this field that the rate of progress ought to be accelerated.

Trusting that the information and opinions stated above will be of use to your subcommittee, I remain,

Respectfully yours,

K. S. SPIEGLER,
*Head, Physical Geochemistry Section.*

NETHERLANDS EMBASSY,
*Washington, D. C., April 21, 1958.*

Mr. M. Q. ROMNEY,
*Public Works and Resources Subcommittee,*
*House Committee on Government Operations,*
*Washington, D. C.*

DEAR MR. ROMNEY: Very shortly after our telephone conversation on the 21st of April, I received a letter from the Governor of Aruba concerning the water purifying installation for city water. The installation is in Balashi on the Island of Aruba. What I did not know, and is of course important for you, is that the plant is not yet in service; but they have sent me the following information about it.

1. The new water plant is based on the evaporation process. About 60 percent of the seawater is evaporated in 6 effects. The temperature for any given effect is about 10° C. higher than that of the effect with the next lower temperature. The heating necessary for the evaporation in any given effect is obtained from the condensing heat from the next higher temperature effect.

The heating for the first effect (the highest temperature) is obtained from condensing heat of low pressure steam. For increasing the heat effect, the cooling heat of the vapour is used for preheating the seawater.

The evaporation process, which has been used now for 30 years in the Netherlands Antilles, has one great enemy: the scale formation that deposits on the heating coils. G. & J. Weir, Ltd., who are building these plants, have found a method to counteract this scale formation through treating the seawater with ferric ions, by which the limes precipitate without forming scale.

2. With this process, the salt and lime quantity in the distillate is, of course, at a minimum. Therefore, to improve the bland taste of the distillate, it is conducted over coral, over which it is aerated and a necessary small quantity of mineral is picked up.

Injections with a solution of 5–10 percent $Na_2CO_3$ and with a solution of 5–10 percent NaOH and 1.5–2.0 percent hexametaphosphate make the water suitable for boiler-feed purposes at a pH of 8.4.

3. The new water plant in Aruba has 5 units, each of which produces 2000 m3/day [530,000 gallons per day].

4. For economic reasons the water project is coupled with an electric powerplant, where back-pressure turbines are operating; meanwhile the exhaust steam is used as heating steam for the evaporator units. This combination makes it difficult to say something exact about prices and costs. But you can reckon for the water-plant an investment cost of $7 million, plus $1 million as the part of the cost of the steam-generating plant allocated to water-plant operations.

5. The evaporation process uses about 17,500 kg/h (38,500 pounds per hour) steam with 1.4 kg/cm² (21 pounds per square inch) and 130° C. per unit and 165 kg/h (363 pounds per hour) steam with 12 kg/cm² (300 pounds per square inch) and 197° C. for the air ejector of the distilling condensor. The condensate from the low pressure steam has a temperature of 118° C. and is conducted back to the steam generating plant. The condensate from the low pressure steam is picked up in the distillate. Electric power necessary for pumping and electrolysis (for ferric chloride production) is about 300 kilowatts per unit, electric power for the steam generating plant and for filter pumping and reservoir pumping not included. The prices of steam and electricity depend on the output of electric power, so that in general no exact prices can be designated.

With all units operating, the cost of the water would be about $0.70 to $0.65 per m³ [$2.66 to $2.47 per 1,000 gallons], apart from the production of electricity.

For the selling price, you must reckon with the profit of the electric powerplant, which can be considerable because of this back-pressure service. True, the present cost price is higher; for the plant has a large reserve for water, steam, and electricity to stimulate new industries on Aruba.

6. The plant operates continuously, and so we need 4 to 5 shifts of personnel. Just for the water plant in each shift there are needed: 1 engineer, 1 control-board operator, 1 evaporator operator, 1 electrolytic cells operator and 1 pump operator. Further, you must reckon with an allocation of part

of the costs of the steam generating plant personnel; this distribution depends again on the production of electricity, so that no exact cost can be designated.

About the costs of maintenance there are no present data, for the plant is not working yet.

7. The seawater is converted to about 60 percent distillate and 40 percent brine. The seawater has a salinity degree of 3.5 percent so that the brine has a salinity degree of about 9 percent; therefore there is no danger of making salt crystals which would precipitate out of solution.

The temperature of the seawater is about 29° C. when pumped up; 139 $m^3/h$ [37,000 gallons per hour] are used for evaporating per unit. Of this, 85 $m^3/h$ [22,440 gallons per hour] leave the distilling condenser with a temperature of 54° C. and are cooled with seawater to 39° C. The 54 $m^3/h$ [14,250 gallons per hour] of rejected brine also have a temperature of 54° C.

The total heat loss is determined by the heat supply (see point 5) and is about 10,000 kw to the storage tanks of the distillate and 1,700 kw to the sea as cooling water.

8. As the new plant is not yet in service, it is, of course, not possible to speak of any actual operating problems.

I also enclose a copy of a report by the Bureau of Economic Affairs of the Island of Aruba.[1]

I hope this information will be satisfactory to you, and I remain,

Very truly yours,

P. VAN DER HEEM,
*Assistant Scientific Attaché, Netherlands Embassy.*

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NEW MEXICO HIGHLANDS UNIVERSITY,
INSTITUTE OF SCIENTIFIC RESEARCH,
*Las Vegas, March 28, 1958.*

HON. ROBERT E. JONES,
*House of Representatives, Washington, D. C.*

MY DEAR MR. JONES: Reference is made to your letter of February 21 concerning the saline water conversion program. I am pleased to note the interest taken by the Congress in saline water conversion and appreciate the opportunity of expressing my views.

In your letter, you listed several categories into which you wish the information divided. I am more familiar with certain aspects of the saline water problem than with others, but I will endeavor to give you something in each category you listed.

1. In regard to the current status of saline water conversion progress here and abroad, it would appear that the pattern is anything but uniform. This is to be expected in that objectives vary greatly. Some foreign countries (e. g., Israel) are hard pressed for drinking water. Others consider the conversion of saline water as a process producing two needed quantities such as drinking water and salt. Others (e. g., United States) are interested primarily in the economic factors of the conversion. Thus, with so many different objectives, the current state of progress is very hard to delineate on a worldwide basis. As to the state of progress in the United States, perhaps a clearer picture is available. At present, the saline water conversion effort is concentrated on the following general processes: Distillation (fossil fuel powered), distillation (solar energy powered), distillation (nuclear fuel powered), membrance processes, freezing processes, liquid-liquid extraction, and miscellaneous small-scale methods for special purposes (e. g., military). These general processes have been evolved from consideration of numerous ideas, and appear to be the most promising. However, one must always seek and encourage fresh approaches, and, indeed, there appears to have been a decline of such new ideas during the past year or two.

Of the seven processes described above, each has attributes and drawbacks. I am sure that the Office of Saline Water has consultant reports which evaluate these general approaches. In general, I feel that while saline water conversion is in the realm of engineering, there is much basic research that remains to be

[1] The report referred to entitled "Aruba's Water and Electricity Project," is available in the subcommittee files.

done in order to iron out the various difficulties peculiar to each general process. Some suggestions are contained in item 3 below.

2. It appears to me that the extent of coordination between the Government and private groups interested in saline water conversions is good in this country. I do not know what the situation is abroad.

The only suggestion that might be advanced is that more universities should be encouraged to participate in the program. I know that the Office of Saline Water has tried in the past to do this; however, the program must include additional aspects of basic research in order to be successful.

3. The rate of progress should, in my opinion, be accelerated. More work should be done on heat transfer, on crystal structure, on the nature of ionic species, on hydrogen bond effects, on crystallization processes, on heat storage, and on electrical properties of dilute solutions, on diffusion and transport, on thermodynamics, on the properties of water, ice, and steam. And especially, more work should be done on double-purpose processes; that is, processes which either produce water for a specific purpose and which, therefore, remove undesirable ingredients while adding desirable ones, or processes which produce water plus another marketable product. For example, in our laboratories, we have been interested in a method of producing ammoniated water which could be used for irrigation purposes. Since many soils need nitrogen, which is frequently added in the form of anhydrous ammonia gas, it would appear that an economic barrier could be surmounted by using an ammoniated resin bed through which the brackish water could be passed exchanging the undesirable metal ions for ammonium ions, thus producing ammoniated water useful as a very dilute liquid fertilizer.

Emphasis should be on the determination of basic physical and chemical data. It is the shortage of such data which, I believe, hinders the development of engineering techniques. In other words, I feel that greater emphasis must be placed on basic research and less on an immediate result. This, of course, implies that the Congress and the Department of the Interior must be patient insofar as "hardware" items are concerned. The problem of saline water conversion is a tough and long-range one. Results can only be expected from thorough investigations which consider the fundamental as well as the applied aspects of the problem. Perhaps the Office of Saline Water has been too long "under the gun"; has been too long required to show an impressive list of hardware in order to secure appropriations to carry on the program. I am of the opinion that the time has come to set up long-range programs, and to project their financing over a period of years.

4. I believe I have answered the question in this item in the discussion above.

5. For the information called for in this item, I refer you to the following papers presented at the symposium on saline water conversion held in Washington Novmeber 4–6, 1957.

Distillation (fossil fuel powered): Papers by W. L. Badger and F. C. Standiford, Kenneth Hickman, Stuart F. Mulford, Allen Cywin.

Distillation (solar energy powered): George O. G. Löf, Joseph J. Strobel.

Distillation (nuclear energy powered): William R. Hainsworth, Donat B. Price, and Mark R. Dusbabek.

Membrane processes: W. S. Gillam and E. H. Sieveka.

Freezing processes: H. M. Hendrickson, R. C. Hines, and H. L. Goering.

Liquid-liquid extraction: Richard R. Davison and Donald H. Hood.

I hope the above is of some use to you. If there is any question or further information desired on a particular point, I would be happy to supply it.

Sincerely yours,

E. GERALD MEYER, *Director.*

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NEW YORK UNIVERSITY,
COLLEGE OF ENGINEERING,
*University Heights, New York, N. Y., March 5, 1958.*

Mr. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*House of Representatives, Washington, D. C.*

DEAR MR. JONES: In response to your letter of February 21, the following information is offered on saline-water conversion. We have conducted research and development in solar distillation, therefore, our comments are restricted

mainly to this field. Since 1954 our work has been sponsored by the Department of the Interior, Office of Saline Water.

1. The current state of progress (both here and abroad) in saline water conversion:

Our group has developed very efficient flat tilted solar stills, capable of producing 1 gallon fresh water daily from a still area of 5 to 6 square feet. These stills could be manufactured at a lower cost than any previous still. Copies of the writer's previous models are being used on an experimental scale in the Sahara and in the Australian Desert.

2. The extent of coordination between the Federal Government, private industry, and other public and private groups, both here and abroad:

The Office of Saline Water has disseminated information quite freely to those who asked for it. Fuel operated, or electrically operated saline water conversion methods are being manufactured by private industry. Solar distillation has attracted a great deal of interest, but stills are not commercially available as yet.

3. Whether the rate of progress ought to be accelerated either in basic research or in engineering applications of known processes, or both; and, if funds are limited, whether basic research or engineering applications should be emphasized:

Sufficient basic research has been carried out during the past 4 years. What is needed is the installation and operation of pilot plant solar stills. The Office of Saline Water has awarded a contract to another organization to do this. It may be best to restrict work to the four most promising major fields, which include solar distillation and to limit activities in other unproven fields.

4. Assuming progress should be hastened, what particular steps might be advantageously taken by the Government to encourage acceleration:

Progress in solar distillation could be accelerated tremendously by giving free hand and ample funds to those who did actual experimental work (not merely calculations and armchair designs). Using an experienced constructor, several small pilot plants should be installed at locations with ample sunshine. The pilot plants should be operated with sea water under expert supervision, in locations where fresh water is urgently needed. In this way, the necessary modifications, or adjustments in design could be made and the actual construction costs can be determined.

5. Various processes under investigation and development, including to the extent available, data on:

(*a*) Solar distillation cost estimates, (*b*) quantity of water converted per day:

The initial investment cost of all components of a solar still installation, of the type developed by us, is estimated at less than $5 per daily gallon fresh water capacity. This estimate is based on commerical mass production and has been made in accordance with the procedure of the Office of Saline Water. The cost of water is estimated at less than $1 per 1,000 gallons fresh water.

(*c*) Source and salinity of water before and after treatment:

Using the solar stills developed by us—pure distilled water is obtained from sea water or other waters of high or low salt content.

In tropical regions water is a scarce and expensive commodity. Salt water is available almost anywhere. Sunshine is available the year around. Fresh water produced by solar stills is urgently needed. Equipment of this type could be used by International Cooperation Administration.

Sincerely yours,

MARIA TELKES,
*Project Director, Solar Energy Laboratory.*

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NUCLEAR DEVELOPMENT CORPORATION OF AMERICA,
*White Plains, N. Y., March 11, 1958.*

PUBLIC WORKS AND RESOURCES SUBCOMMITTEE OF THE
COMMITTEE ON GOVERNMENT OPERATIONS,
*House Office Building, Washington, D. C.*
(Attention: Mr. Robert E. Jones, Chairman.)

GENTLEMEN: This is in reply to your inquiry of February 20 asking our views on various aspects of saline-water conversion. As you already know, our firm's primary activity is in the field of applied atomic energy including reactors for power, industrial use, and research. We have, however, performed for the in-

terior Department's Office of Saline Water a research program into one means of purifying saline water. This work has been completed and our reports have been submitted to the Office of Saline Water. A number of years ago we also performed a survey of the field for the Conservation Foundation and this report was published as a book: Fresh Water from the Ocean—For Cities, Industry, and Irrigation, by Cecil B. Ellis, and members of the staff of NDA, Ronald Press Co., New York City 1954.

Since our activity in the saline-water program has been quite limited in the last year or two, we would think that our answers to your questions would in some cases not be based on enough up-to-date information to be of proper significance. Therefore, we will answer only those of your questions on which our opinion might be of value to you.

1. No opinion.

2. The extent of coordination between Federal Government, private industry, and other groups both here and abroad, as we were privileged to witness it during our association with the Office of Saline Water, was excellent. Our relationship with the Office of Saline Water and their activity in promoting interchange of information with other groups was, in our opinion, exemplary.

3. No opinion.

4. No opinion.

5. The process we investigated was one on very high-pressure distillation. The pressure was in excess of the critical pressure of pure water and, hence, the process was referred to as supercritical distillation. Our work on the process indicated that it was technically feasible, that pure water could be produced by this process, but that certain scaling problems were severe enough so that any further work on this process should be postponed until such time as a solution of the scaling problem itself had been obtained. No conclusive economic data could be presented until the scaling problem had been solved. In this process "scaling" refers to the information of heavy salt deposits on the heat-transfer surfaces employed in the system. The results of our work have been presented in considerable detail in a series of reports to the Office of Saline Water and are summarized in a report: NDA 32–20. Program Summary Report—Extraction of Fresh Water from Sea Water in Super-Critical State, William A. Loeb, March 1, 1957.

Very truly yours,

WILLARD S. MOTT,
*Manager, Contract Negotiations.*

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PACIFIC GAS AND ELECTRIC CO.,
*San Francisco, February 26, 1958.*

Subject: Saline Water Conversion Program

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee of the Committee on Government Operations, House Office Building, Washington, D. C.*

DEAR MR. JONES: This refers to your letter of February 12, 1958, requesting my comments in connection with certain specific items relating to the Federal Government's saline water conversion program.

I will comment briefly on the five items listed in your letter:

1. The Federal Government's interest in saline water conversion has served to stimulate considerable interest in the problems involved. The activities carried on by the Department of the Interior have been successful in establishing a reasonable basis of comparing the overall costs of various methods. Previously there appeared to be considerable confusion and the initial assumptions by different individuals as a basis of estimating costs resulted in figures which were not comparable.

The most important processes under investigation and development have now been fairly well cataloged through reports of the Department of the Interior. It has also been brought out that emphasis by foreign countries has, in a number of instances, been placed in an area which does not necessarily coincide with the major activities in this country. I do not believe that this should be interpreted as a situation which requires an effort at coordination. Economic and physical conditions in foreign countries have probably been largely responsible for the different approach.

2. One of the recommendations made by the distillation committee at the Washington meeting on November 4–6, 1957, was that "present efforts by various foreign countries should be encouraged by any reasonable means and more active exchange of information should be fostered." As to the extent of coordination between the Federal Government, private industry, and other public and private groups in this country, it is my personal feeling that efforts by the Department of the Interior have been adequate up to the present time. However, the comments given below in items 4 and 5 contain some suggestions which might produce further constructive results.

3. Another comment made by the distillation committee in its list of recommendations was that although "substantial progress has been made * * * it is the impression of this committee that the program has been hampered by the lack of funds." It was the opinion of our committee that funds should be made available for certain specific activities which are briefly reviewed in item 4 below.

4. Our distillation committee made specific recommendations for accelerating the program along those lines which appear to indicate the greatest promise of immediate results. The recommendations which are briefly recapitulated below are based upon the conclusion that the problems of scale formation and corrosion at temperatures above 190° F. have been and still are the major problems which stand in the way of many otherwise promising distillation processes. For the same reason, the committee felt that more active attention should be given to the development of low-temperature distillation processes where the problems of scale formation and corrosion are minimized.

Specifically the committee recommended:

(*a*) "The immediate initiation of a long-term investigation of factors affecting the mechanism of scale formation and any related effects of corrosion."

(*b*) "A more extensive study should be made of methods of improving heat transfer." In this connection, the Hickman rotary still shows great promise in small sizes and therefore would apply at the present time especially in that area of utilization. The research work being conducted by Drs. Dodge and Ashaya in connection with so-called dropwise condensation is of considerable interest. These techniques are fundamentally applicable to large installations and any improvement in heat transfer rates will be directly reflected in a reduction in first cost of the installation and thereby bring us closer to an economically feasible method of distillation on a large scale.

(*c*) "A more extensive study should be pursued in connection with the feasibility and cost of flash distillation, particularly at low-temperature levels but also in higher pressure multistage units." The need for activity in this area is obvious in the light of the initial paragraphs under this item 4.

5. Another important conclusion of the distillation committee is applicable to this item. Although an acceptable basis for conversion cost estimates has been developed by the Department of the Interior, it was the committee's feeling that "several promising processes have reached the stage where it is essential that a more accurate knowledge be obtained of investment and operating costs." Up to the present most of the work has been done at a research level and it is essential that these processes now be reviewed more objectively from the standpoint of the various technical and cost factors. Therefore the committee recommended that "a careful cost study and analysis be made by a qualified engineering firm with respect to 2 or 3 of the most promising distillation schemes." The committee felt that an engineering study of this nature would probably require an outlay of approximately $250,000. It was the committee's feeling that funds should be released immediately for such a study and that very careful consideration should be given to the qualifications of any engineering firm selected for this important phase of the work. The important point is that, although a satisfactory basis for comparable cost estimates has been established, the technical and physical problems that influence such costs must now be carefully investigated by competent engineers rather than researchers.

I hope that my comments have not been too lengthy and that they will be of some value to your committee. It should be understood that the opinions and suggestions which I have advanced are either those of the committee of which I was chairman in Washington last summer or are my own.

Very truly yours,

V. F. ESTCOURT.

THE PERMUTIT CO.,
*New York, N. Y., March 26, 1958.*

ROBERT E. JONES,
*Member of Congress, Chairman, Public Works and Resources Subcommittee, House of Representatives, Washington, D. C.*

DEAR SIR: Your letter of February 20, in connection with the saline water conversion program, has been passed to me for response.

You have requested that we furnish the subcommittee with our views in reference to progress and prospects in the field of saline water conversion. Below are our comments in reference to the several items you have mentioned:

1. The current state of progress in saline water conversion has been summarized very well in the papers presented at the saline water conversion symposium sponsored by the Interior Department's Office of Saline Water in Washington in November 1957. We have been doing some research in connection with the development of improved ion exchange membranes and an improved electrodialysis device for the purification of brackish waters. Our work has indicated that such electrodialysis ion exchange membrane equipment is not feasible for economic treatment of sea water.

2. The Office of Saline Water has, we believe, maintained good coordination between the Federal Government, private industry, and other public and private groups in this work, to the best of our knowledge, both here and abroad.

3. Basic research should be stimulated in this field in order to lead to variations on present-day approaches to this problem. More complete engineering evaluations are required of the several known processes so that their economic feasibility can be determined for various situations. This may require further expenditure on trial or pilot plant operation of the known processes. If funds are limited, basic research should be stimulated.

4. We believe that it would be particularly desirable for the Government to make a complete survey of the availability of brackish waters in various water-shortage areas of the United States at as many localities as possible, in respect to both potential flow of water available as well as its quality at the wells. This would then make it possible to make a careful market analysis to see where brackish-water-conversion equipment can be employed with economic benefit. If such market data were available and it indicated where brackish-water-conversion equipment could be employed economically, there would be much more incentive on the part of industry to devote large-scale efforts in this field. At present, although there appears to be a potential market, its scope is hazy.

5. The only processes for treatment of saline waters that we have currently under investigation are:

(*a*) Desalting of sea water for emergency use for drinking purposes, employing desalting briquets. This process is not economically feasible for large-scale production of fresh water from sea water.

(*b*) The electrodialysis process employing ion exchange membranes. Our anticipated costs are similar to those reported by others at the above-mentioned conference.

If we can be of any further assistance to you, please do not hesitate to call upon us.

Sincerely yours,

THE PERMUTIT CO.,
*A Division of Pfaudler Permutit, Inc.*
M. E. GILWOOD,
*Director of Research.*

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POLYTECHNIC INSTITUTE OF BROOKLYN,
DEPARTMENT OF CHEMISTRY,
*March 3, 1958.*

Hon. ROBERT E. JONES,
*Member of Congress, Chairman, Public Works and Resources Subcommittee, House of Representatives, Washington, D. C.*

DEAR SIR: It is a pleasure to be of assistance to your committee in its study of the Federal Government's water-saline program. My brief answers to your specific questions are listed below.

1. *Current state of progress.*—Overseas, where the problem is already urgent, water conversion is carried out in England, Holland, South Africa, and the Near

East largely by membrane electrodialysis. These foreign groups surveyed all conversion processes for both sea and brackish water, and decided upon the membrane process as against all others. Their costs are fairly high, largely because they use heavy, cumbersome equipment and fabrication methods. Their total research and development costs were about $4 million (United States equivalent), but there was considerable duplication.

In the United States, only one company has developed a membrane process, but the quality of its membranes and engineering design are inferior to foreign materials and methods. Two other American companies are currently making membranes but not equipment; their membranes appear to be superior to the foreign product.

The Office of Saline Water has supported research and development in several directions. Two processes were brought through the pilot-plant stage, a membrane process and a distillation process. The cost estimates for the membrane process were not encouraging, but this was because the engineering study was carried out using the inferior membranes and designs mentioned above. With regard to distillation processes, it appears that more complicated designs which lead to lower heat consumption also cost so much more to fabricate and maintain that we seem to be about where we were several years ago in terms of total cost. Of the many other processes investigated, none give costs within striking distances of maximum allowable figures.

2. *Extent of coordination.*—The Office of Saline Water has encouraged all possible coordination by sponsoring research and development in both profit and nonprofit institutions, and by facilitating the exchange of information. This has inevitably led to the effort being spread too thin. Companies are reluctant to underwrite development costs, and have looked to the Government for support. Foreign groups have been unwilling to give or sell their know how in usable form.

3. *Acceleration.*—At this time, in the absence of any new ideas on conversion, it would appear logical for a more complete development of the one process that has shown the only practical promise, namely the conversion of brackish water using membrane electrodialysis. Conversion of brackish water would help many communities throughout the United States at this time. Experience gained in solving this simpler problem would help in attacking the more difficult problem of large-scale sea water conversion. There are good technical reasons for believing that the membrane process can be improved so as to apply to sea water also.

If funds are available, a program of basic research in this area should be continued, but restricted to the laboratory level.

4. *Government steps.*—The Government should encourage the Office of Saline Water to concentrate in a limited area for the purpose of achieving a limited objective.

5. *Cost estimates.*—I estimate the cost of conversion of a typical 4,000 parts per million brackish water down to a potable level of 250 parts per million, will be not more than 21 cents per 1,000 gallons for a town or city sized installation. This estimate includes all cost components, using the conservative cost estimate formula of the Office of Saline Water.

Last October I prepared a memorandum for the Office of Saline Water, which answers most of your questions in detail. Two copies are enclosed, with the salient points marked for your convenience. I will be most pleased to supply your committee with any further assistance or information.

Respectfully yours,

H. P. GREGOR,
*Professor of Chemistry.*

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BALTIMORE, MD., *March 18, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*House Office Building, Washington, D. C.*

DEAR CONGRESSMAN JONES: I have read with interest your letter of February 18, 1958, requesting that I submit an opinion on a number of phases of the saline water conversion program being administered by the Secretary of the Interior.

Consideration has been given to the several questions you have propounded and upon which you requested my comment. I presume you desire merely a brief opinion on each of the several items, to guide the action of your commit-

tee. I am answering these in the order in which they have been submitted.

1. Through the effort and administration of the Office of Saline Water, studies and evaluations of miscellaneous processes for producing usable fresh water from the sea and other saline sources have been made. Numerous investigations in other countries have, in general, followed along the same pattern of research and development as has taken place here. The widespread interest and research investigations in many countries throughout the world should point the way to the selection of economic and practical large-scale conversion plants. The research work which has been conducted, both here and in other countries, has been an invaluable contribution on the subject and should be expanded.

2. It is my personal opinion that it is the function of the Federal Government to stimulate interest in this subject and serve as a factfinding body for the dissemination of reliable information based on research on existing and new processes which are now or may become available. Private industries' functions and municipal and State government roles should be directed to stimulating the program by cooperation with the Federal Government to the extent of furnishing, in whole or in part, the necessary financial assistance which is required to develop worthwhile processes. This should lead to the installation of largescale plants of selected processes which are best suited to meet local conditions.

Much is to be gained by active cooperation with private and governmental agencies in foreign countries. This should embody not only a prorgam for exchange of scientific information, but active cooperation, financially, and through other channels. An international policy of permitting exchange of scientific data in this field would undoubtedly be productive and mutually helpful to all peoples of the world.

3 and 4. There is no doubt that the program being administered by the Office of Saline Water should be expanded to meet urgent national water requirements. It is reliably predicted that the national water requirements will be doubled by 1975. A definite factor in solving the water problem in this country is the acquisition of fresh water from saline sources in many areas. To speed up the rate of progress would require much larger appropriations than are now available. Without such assistance, progress in this field wil undoubtedly lag far behind the country's needs.

5. The most complete assembly of data in any one place is available in the Office of Saline Water. It is timely to critically analyze these data, integrating the information here with findings in similar investigations abroad. To do a thoroughgoing job, which is needed, will require sufficient funds that may not now be in hand; however, I think it is imperative that such a program of evaluation be established. It is desirable also to prepare an inventory of all sources of inland saline water supplies, their chemical quality, and availability and suitability for conversion processes.

I trust that this brief summary may be of some assistance to you. If you wish me to amplify the statements I have made here, or to furnish you with more specific information, I shall be very glad to do so.

Sincerely yours,

SHEPPARD T. POWELL,
*Consulting Engineer.*

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PURDUE RESEARCH FOUNDATION,
*Lafayette, Ind., February 21, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*House of Representatives, Washington, D. C.*

DEAR SIR: This is in reply to your letter of February 12 asking for a statement regarding the Federal Government's saline water conversion program. I am making my remarks with particular reference to the use of solar energy, since I was chairman of the solar energy session of the Saline Water Symposium held in November 1957 in Washington, D. C.

My answers follow the questions raised by you:

1. The current state of progress both here and abroad in saline water conversion.

Processes for the use of solar energy have been lagging in the United States as compared to some other parts of the world. The reason for this lag is that

the cost of fuel in the United States is less than it is in most other parts of the world. Where fuel costs are high, there is more immediate desire to use solar energy.

Since the use of solar energy appears to be a desirable mechanism for saline water conversion, more studies on the use of solar energy should be supported by the Government's saline water conversion program, regardless of the immediate prospects of economic success.

2. The extent of coordination between the Federal Government, private industry, and other public and private groups, both here and abroad.

The extent of coordination appears to be reasonably good, and I have no suggestions to make in this particular area.

3. Whether the rate of progress ought to be accelerated.

As noted in the answer to question 1, it is believed that the rate of progress on utilization of solar energy for saline water conversion should be accelerated.

4. If so, what particular steps might be advantageously taken by the Government to encourage acceleration?

(*a*) Wherever an inquiring mind is found with a good suggestion for the utilization of solar energy, the idea should be given support. The amount of energy necessary to separate dissolved salts from water as they exist in sea water is considerably less than the amount of energy required to distill water, yet the only processes for the use of solar energy which have received support are those for solar distillation. Means should be found to encourage ideas for the separation of dissolved salts from water by means other than distillation using solar energy as the source.

(*b*) As noted in the answer to item 1 above, there has been little or no pilot-plant development of solar energy distillation processes in the United States because of the present low cost of fuels in the United States. From a data gathering viewpoint, it would be most desirable to build and operate a sizable pilot plant for the recovery of saline water by the use of solar energy. The data obtained from such an operation might prove that the present speculation that such operation is economically unsound is incorrect. Even if the operation of such a plant did prove that such operation was economically unsound in the United States, the information gathered would be very valuable. It is reasonable to expect a time will come when fuel costs will be relatively higher in the United States. Thus, with data available in the future, a solar energy saline water conversion plant might be economically sound.

(*c*) As a part of a sound foreign-aid program, it might be desirable to erect a pilot plant to use solar energy for saline water conversion in some part of the world other than the United States. The only strings that would be put on such a plant would be that the data gathered would be freely published and the information would be gathered in such a way as to be technically sound. Such a venture would be valuable not only to the saline water conversion program but would make good sense as valuable aid to our friends in other countries where energy costs are much higher than ours.

5. Various processes under investigation and development, with emphasis on conversion cost estimates, to the extent available.

As noted in the answers to the questions raised above, the chief reason given for not building a pilot plant for the conversion of saline water using solar energy is that such a plant would be economically unsound in the United States. This statement itself is largely speculation since there are insufficient data to be sure. In order that such a pilot plant would provide the greatest possible information, it would contain elements from all of the more than half dozen different designs that have been suggested.

Only by comparing these designs on a large enough scale and on a side-by-side basis can the question of economic feasibility and technical reliability as well as the life of the materials be finally judged.

I hope you find this information helpful.

Sincerely yours,

RALPH A. MORGAN,
*Research Director.*

RADIO CORPORATION OF AMERICA,
RCA LABORATORIES,
*Princeton, N. J., March 13, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*House of Representatives, Washington, D. C.*

DEAR MR. JONES: This is in answer to your inquiry of February 21, 1958, asking for information on the state of research and development in saline water conversion.

For the past several years RCA Laboratories has been doing research on thermoelectric junctions for cooling. There are many potential applications for devices based on this effect. The ones with which we have been primarily concerned are those applicable to electronic refrigeration and electronic air conditioning.

As a result of this work, it is obvious to us that the techniques which are being worked on could be applied in the development of a water-purification plant. The thermo junctions we are developing would be applied as a heat pump to regenerate a large part of the heat of vaporization. It appears to have promise, after sufficient development, of offering advantages over possible alternate systems, such as one using a mechanical heat pump.

Knowing their interest in this area, we solicited the Department of the Interior in October 1956, offering to undertake a study program to determine the feasibility of a thermoelectric distillation system for the purification of water and to build a pilot model of such a system for evaluation.

In February 1957 we were informed that the Department of the Interior had completed a review of our proposal with their consultants and with representatives of the Department of Defense. They did not feel that the system proposed offered sufficient potential advantages over present water purification methods and equipments to warrant the expenditure of military research and development funds.

Since we were not able to find Government support for the project, we have not pursued this particular application of thermo junctions further. We are, however, continuing research in the general field to thermoelectric heat pumping, and also in the direct generation of electricity by means of thermo junctions, which is closely related. We are enthusastic over the possibilities in this line of research and feel that it has promise in several possible applications. We are actively seeking Government support of the basic research and for applications in areas where we think there is military or other interest in the principle. We still feel that its application to water purification has certain potential advantages not present in other systems.

Because our primary interest has been in the development of thermoelectric junctions and their applications, we have not made a broad study of the general field of water purification. We are not, therefore, in a position to offer views on the progress and prospects in this field generally.

If you wish any further information on our activities or if you would like a copy of the proposal we submitted to the Department of the Interior, we would be happy to supply it to you.

Very truly yours,

R. S. HOLMES,
*Director, Research Contracts.*

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SINGMASTER & BREYER,
METALLURGICAL AND CHEMICAL PROCESS ENGINEERS,
*New York, N. Y., April 11, 1958.*

Mr. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*House Office Building, Washington, D. C.*

DEAR MR. JONES: In answer to your letter of April 8, I am happy to submit whatever help I can give you to answer your questions.

1. The current state of progress was well covered at the symposium held jointly by the Office of Saline Waters and the National Academy of Science in Washington November 3, 4, and 5, 1957. The curve presented by OSW at that time showed the extremely rapid growth of salt water conversion installations which now total probably 15 million gallons per day. I have no doubt that the present day rapid technological developments are bringing down the

cost of water from the sea. This will result in an ever-increasing number of installations justifying the steep upward slope of the curve.

2. Coordination between Federal Government and others. By the creation of OSW in 1952 the Government has sponsored a large amount of research work and some pilot-plant work. These efforts have undoubtedly resulted in advancement of the art and have definitely benefited those private industries who had research contracts. On the other hand, I do not know that any of the leading American manufacturers of salt water conversion equipment, who are in a position to furnish complete plants, have had any appreciable support from the Federal Government. Most of these firms have developed their own processes and equipment and are ready and anxious to sell major sized plants.

As to the situation abroad, I have no definite knowledge except that the Governments of Great Britain, Netherlands, France, and Russia all have agencies working in the saline-water field.

3. The rate of progress has accelerated markedly, especially in the recent past. We constantly receive information on new processes and equipment indicating an awakening by industry of the vast potential that lies ahead and the efforts to find cheaper and better ways of solving the problem. Much is being done outside the sponsorship of the Federal Government. The best incentive to further development is the profit motive for private industry. This will be greatly helped if our American manufacturers, engineers, and constructors can sell and build some plants. In the foreign field this might require governmental assistance in financing, credit, and convertibility guaranties, etc. From the domestic scene, this would need financial assistance in whole or in part by the Government since most communities who will need water from the sea in the future are not yet willing to pay the full price for it.

4. While this question has been answered in part by the preceding paragraph, let me be specific. After 6 years of research it is time to take this business out of the test tube. Its feasibility has already been proven by the volume of commercial plants operating daily in many parts of the world outside of the United States. I respectfully suggest it is time now to build one or two working plants in the United States, using the best accepted and proved processes. Only in this way can we gain the real operating knowledge to accelerate further development.

In addition to the above suggestion, of course, study should continue on the numerous new processes and equipment which are constantly being suggested. Where such new ideas appear promising upon research work, they can then be incorporated in the working plants suggested above.

It may be helpful to your thinking to look at the statement we wrote sometime ago (and appended to this letter) suggesting the analogy between atomic energy electric powerplants and our saline water conversion program.

5. Regarding various processes under investigation, the Office of Saline Water certainly can supply you with the most comprehensive list. To the best of my knowledge, only two of these processes have been advanced to the pilot-plant stage, namely, the W. L. Badger long tube vertical evaporator and the Hickman still. Outside the work being done by OSW we know at least five major American manufacturers whose processes are beyond the investigation and development stage to the point where they are ready to sell and guarantee results.

(*a*) Conversion cost estimates run all over the lot. The Maxim Silencer Co. was quoted in the newspapers on 20 cents per 1,000-gallon water-production cost. We understand they feel they were misquoted and never intended the 20 cents to be a complete cost. Two other processes claim costs between 30 and 45 cents per 1,000 gallons. These are "on paper" costs. I do know several of the leading manufacturers, including Maxim, who talk more realistically of costs from 60 cents to $1 per 1,000 gallons. I have tried to put this cost question on a solid basis in my article in Consulting Engineer, to which you were kind enough to refer. As a professional engineer, this article had to be written on a factual, conservative basis, and I might venture that already today somewhat lower figures than I indicated can be obtained.

(*b*) All the leading manufacturers can offer plants with capacities from 1 million to 5 million gallons per day. One of these is working on an inquiry for a 20 million-gallon-per-day plant. I do not think anybody is ready for 100 million gallons per day. We must walk before we run, and this country badly needs some working plants in the 1 million to 5 million gallon-per-day size.

(*c*) The salinity of full-strength ocean water varies in different parts of the world, running from approximately 17,000 parts per million of total solids (80 percent salt) to as high as 43,000 parts per million in the Persian Gulf. The

warmer waters in the Caribbean run about 35,000 parts per million. The distillation processes reduce these waters to less than 10 parts per million total solids. Getting away from full-strength ocean water, brackish waters containing up to 5,000 parts per million appear to be best handled by the electric membrane processes which reduce their salinity to 500 parts per million.

Obviously, the subject of your questions is much too broad to be covered even by this lengthy letter, but I trust you will find these answers of some value. If you should find an opportunity to come to New York, I would be happy to discuss this with you more fully and more freely than could be done by writing or in committee meetings.

Very truly yours,

G. E. SONDERMAN.

APPENDIX TO LETTER TO MR. ROBERT E. JONES, CONGRESS OF THE UNITED STATES

No matter who provides it, water is going to cost more—never less. It is simply the more complex distribution of natural supplies from wherever nature dumps them to the more distant consumers whom nature has not blessed.

One out remains—let us distill the sea water ourselves and not wait on natural distillation, i. e., rainfall. Certainly this offers real hope to those coastal areas in semiarid regions that find it increasingly costly to get more water. Everybody knows it can be done but—it costs too much.

Has this same thought—"It costs too much"—kept us from building atomic energy electric powerplants? No—the recognition of the limitations of oil and gas fuel, both as to total reserves and increased cost of supply, has made us willing to invest money in developing nuclear energy for the future. The Nation, through the AEC, has contributed funds to assist local electric utilities and manufacturers who are also contributing generously to the future power supply of America. Of course, the early nuclear-generated electricity will cost from 2 to 5 times the present normal cost. But that hasn't stopped us from preparing for the future when present sources of energy will cost more and nuclear energy will cost less.

Why not do the same with salt-water conversion plants for making fresh water? We have the technology, the technical means are known—we need to go ahead and build some plants for demonstration and to develop the future. After all, this is the only way to actually increase the supply of water—all other proposals merely redistribute or conserve it.

G. E. SONDERMAN.

FEBRUARY 17, 1958.

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SUBMITTED BY MR. LOCKE WHITE, JR., ASSISTANT DIRECTOR, SOUTHERN RESEARCH INSTITUTE

Proposed testimony on the saline-water program:

My name is Locke White, Jr. I am here as assistant director of Southern Research Institute, Birmingham, Ala. We have a research and development contract under the Office of Saline Water.

As you gentlemen know, Mr. Jones asked us about 6 weeks ago to comment on 5 aspects of the saline-water program. I believe that my testimony will be most useful to you if I organize it around those 5 aspects. My doing so may help you to distinguish the areas in which we claim competence from those in which we do not.

1. The first subject was "the current state of progress (both here and abroad) in saline-water conversion." We are generally aware of the status of both the overall problem and most of the major approaches to a solution. But we have not attempted a serious appraisal of the overall status. We have no special viewpoint that justifies us in taking issue with the published reports from the international symposium on saline water conversion.

2. The second subject was "the extent of coordination between the Federal Government, private industry, and other public and private groups, both here and abroad." On this point we speak with conviction. Coordination appears to us to be good. The Office of Saline Water maintains close contact with our work. In so doing, the Office always reports to us quite adequately an progress by their other contractors and by other organizations working in the field. In none of the Government-sponsored projects for which I have been responsible at Southern Research Institute has the sponsoring agency tried more conscientiously to keep

us informed of relevant but unpublished work. With other agencies, we have usually felt hampered by not knowing all that we thought we should about what other people were doing. I am sure that often we have only felt hampered, when the work really did not suffer at all; but sometimes the work certainly has suffered. In contrast, the Office of Saline Water has never frustrated us in that way.

3 and 4. The third and fourth subjects were closely related. They were "whether the rate of progress ought to be accelerated either in basic research or in engineering applications of known processes, or both; and, if funds are limited, whether basic research or engineering applications should be emphasized"; and "assuming progress should be hastened, what particular steps might be advantageously taken by the Government to encourage acceleration."

No one can question that acceleration would be desirable at the right price from the right people. Everyone knows that some people—fortunately not yet very many in my State of Alabama—are suffering acutely from shortages of fresh water. But we at Southern Research Institute are not competent to judge whether those people suffer acutely enough to justify accelerating the program, or whether the Federal Government ought to share the cost of accelerating.

On one essential point, however, I have a strong conviction, and I believe that my associates share it. There is every reason to be confident, I believe, that, with more funds, the Office of Saline Water can continue to produce the kind of new ideas that will eventually make the conversion of saline water profitable. For me to say so represents a sharp change from my attitude when first I became aware of the Office's program. I remember quite well my pessimism when first I saw the Office's review of what had been done and its appeal for new ideas and radical improvements. I thought, I am somewhat ashamed to admit, that everything important in this field had already been invented, and that any remaining progress would come, in the vernacular, only by slicing a little thinner what we already had.

Yet I now feel quite differently. The thinking stimulated by the Office has been highly creative and far more productive than I thought it could be, within the financial limitations of the Office. In consequence, we have a good deal of confidence that more funds for the Office would continue to produce increasingly rapid progress.

Next, although we have no specific recommendation about the distribution of funds between research and development, we are deeply suspicious of the natural tendency to press too soon for practical results. We cannot deny that some kinds of improvements cannot be accomplished until a process is tried on a large scale. So, except to the extent that money is a consideration, more large-scale tests are in order.

But money is always a consideration, and large-scale tests usually cost more than many, many small-scale tests. So, until Congress appropriates much more to the Office than it has so far, we would advocate being very careful to extract the utmost information from small-scale tests before proceeding to demonstration-scale units. For one thing, we deeply fear the effect on public opinion if the first large-scale, really expensive unit is unsuccessful. More promising approaches that come along later would suffer immeasurably from its failure.

5. The fifth subject called for details on the process on which we are working—the cost, quantity, and quality of the water that it can produce. We are trying to determine those factors—cost, quantity, and quality—for the so-called osmionic process. It was invented for the Office by Dr. George W. Murphy. It is, in our judgment, an extremely ingenious concept.

Our task is to work out the practical application of the basic concept. Our work has not yet reached a stage that justifies any very positive statements about its ultimate cost and efficiency. We have established some important design principles that go beyond Dr. Murphy's original work for the Office. In a very small laboratory unit, we have demonstrated that the design equations are correct. We have just completed a much larger unit with which we hope now to obtain meaningful cost data.

We can now refine two details of the cost estimate that Dr. Murphy included in his report to the Office in September 1955. First, membranes in quantity will cost, for the immediate future, 3 to 4 times as much as he estimated. But on the other hand, going from his single stage to a double stage, and also going

from his cocurrent to counter-current flow, will produce about threefold improvement. So the effects of refining these two details largely cancel each other and leave the current estimate very little higher than the $0.30 per 1,000 gallons that Dr. Murphy estimated. But the figure is certainly not firm, because there is still no experimental basis for predicting the useful life of the membranes in osmionic service.

If more details on any of the subjects I have discussed would help you, I shall be glad to try to give them to you.

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AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS,
*College Station, Tex., March 5, 1958.*

Reference: Your letter of February 20, 1958.

HON. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*Washington, D. C.*

DEAR SIR: First, allow me to thank you for the honor and opportunity of presenting my ideas to the Resources Subcommittee and the Committee on Government Operations, United States House of Representatives concerning the general status of the saline water program administered by the Department of the Interior, Saline Water Office.

Before answering your specific questions, I would like to state that the Saline Water Office has been most cooperative and helpful in regard to the project supervised in our laboratory on the investigation of solvent extraction as a process for the desalination of sea water. The only problems we have entailed are those which could be traced more or less directly to the lack of funds to carry out the program that we have felt most appropriate and most advised.

Two men on Mr. Jenkins' staff, with whom I am best acquainted, Mr. Joseph Stroebel and Mr. W. S. Gillam, are doing what I think is an excellent job in coordinating the program and have been extremely helpful and efficient in administering our contract both in terms of direct and indirect assistance.

I will now attempt to answer the questions in the order in which they were asked:

1. Current state of progress both here and abroad concerning saline-water conversion.

Progress in the saline-water conversion during the past 5 years by various research laboratories in the country and abroad has been considerable. Until now it appears that the most practical results have been obtained through concentrated effort on older types of methods such as distillation and freezing. However, the use of ionic membranes has shown very good results, particularly for brackish-type waters. Newer methods, such as the one on which we are working, have shown good progress but since these are investigations of fundamentals involved, practical results have not yet materialized. There is every reason to believe that continued effort in these directions will yield dividends.

2. The extent of coordination between the Federal Government, private industry, and other public and private groups both here and abroad.

I am not well informed about the condition abroad concerning the coordination of these groups in the saline-water program. In this country there seems to be only limited interest on the part of private enterprise in this type of investigation. The reasons seem clear in that the product of the effort is a required commodity, not one which will realize large profits. For this reason it is not expected that private industry will enter the picture to any great extent until the basic effort, sponsored by Federal Government, shows a workable process in which industry would like to have a stake.

It is a bit alarming that State governments in general have not considered this problem in their bailiwick of sponsorship. This is even true of those States such as Texas, Oklahoma, New Mexico, Arizona, Nevada, and Utah, where such processes are most needed. It is my understanding, however, that California has put a considerable amount of money into saline-water investigations. There are many problems in this field which could be best handled at the State level, and these governments should be encouraged to undertake such activities. Texas has not been greatly interested in this endeavor, although considerable amount of money is currently being appropriated for conservation measures.

3. Whether the rate of progress ought to be accelerated, either in basic research or engineering application of known processes, or both, and, if funds are limited, whether basic research or engineering application should be emphasized.

Acceleration of present program in both the areas of basic research and engineering application of known processes is desirable. We all must agree that water is extremely important to national economy as a resource and should be provided at the lowest possible cost to those areas of the world and the Nation which are underdeveloped because of lack of this commodity. Research of this type can seldom be accomplished on a crash program basis because it is necessary that the fundamental knowledge be available. This, then, can be applied at any time to the problem at hand. During the next 20 years, the population increases and increased standard of living will put greater demands on the water than have ever been realized before. Along with this goes the problem of increased utilization of agricultural lands and increased water supply for industry and for municipalities. This appears to be as great a need as currently exists in this country.

If the choice must be made, because of limited funds, between basic research and engineering applications, it is my opinion that basic research should be the last to receive monetary cuts and should be accelerated even at the expense of engineering applications. When need becomes critical, it is always possible to undertake a crash program in developing engineering applications. This is not, nor is ever, true, in the case of fundamental research.

4. Assuming progress should be hastened, what particular steps might be advantageously taken by the Government to encourage acceleration?

The greatest single thing that the Government could do in behalf of accelerating this program is to establish a continuing type of support for the research groups in this country who are undertaking a study of this problem. Support should not be on a year-to-year basis, as is currently being done. There should be established at these places a unit of research people who are interested and capable to work on the problem so that they continue their effort from year to year without fear of having to look elsewhere for gainful employment. Without this, it will never be possible to obtain people who are qualified and able to attack a problem which is as difficult and as important as this one. In our own particular case, we feel that probably 30 percent more progress could have been made through the past 5 years had it been determined when the research was initiated that this program would be continued for 5 years and, thus, allow personnel acquisition and continued interest on the part of the people concerned. It would be difficult for me to overemphasize the importance of this point.

The second point is that, in the long haul, the Government will probably realize more for its investment if these research funds are centered around truly research organizations, such as academic institutions and some of the better research foundations. This will not only provide for obtaining information in the immediate area of desalination, but will also assist in training personnel that can then continue in the field as a professional means of livelihood.

5. Various processes under investigation and development, including, to the extent available, data on—

(*a*) conversion-cost estimates, including all cost components on which the estimates are based;

(*b*) the quantity of water converted per day;

(*c*) sources of salinity of water before and after treatment.

I don't believe that I am qualified to answer this question without considerable library research, and feel that I would end up in approximately the same position that is evidenced by the annual reports provided by the Office of Saline Water. It is my personal feeling that, while this question is certainly of paramount importance, it is difficult to judge any process wholly on cost data since the various processes are not comparable in terms of stage of the development of knowledge in the art. Each process should be judged upon its potential. Such judgment can be based on clear evidence of difficulties which are evidenced in case of many processes and how difficult these barriers will be to circumvent.

Wishing you every success in your preliminary evaluation of the Government saline water program.

Respectfully yours,

DONALD W. HOOD,
*Associate Professor.*

THE UNIVERSITY OF TEXAS,
*Austin, February 14, 1958.*

Mr. ROBERT E. JONES,
*Member of Congress, Chairman, Public Works and Resources Subcommittee, House Office Building, Washington, D. C.*

DEAR CONGRESSMAN JONES: In response to your letter of February 12, I attach herewith a reprint of a paper just published in Refrigerating Engineering that will give some information in answer to your questions 1 and 2. The limited progress in saline-water research has been in some measure, related to the small allowance of funds that were made available for the project by Congress, but the coordination and cooperation with industry has been of a much higher order than I have usually experienced with federally directed research programs.

The future rate of progress will be retarded if ample financial support is not extended to the project at this stage. Much of the work done to date has been of a laboratory research and development type. One or two of the methods under development have just reached the pilot-plant stage, while other methods are already under development as pilot-plant demonstrations.

The step-up in supporting funds needed as any one of the methods under investigation passes from the laboratory to the pilot-plant level of development is very marked. Pilot plants cannot be built on small appropriations allowed for laboratory investigations.

I would recommend that your committee recognize that the present state of progress in the saline-water program will cost much more per experimental year to keep the same number of investigators and contractors at work than was necessary in the early stages of this investigation, when it could be housed and carried on in existing commercial and university laboratories with limited personnel.

The principal steps now necessary are (1) to request the Interior Department to proceed on development facets of the projects and (2) furnish them with sufficient appropriation to support this full-blown program.

I believe the answer to your fifth question can be obtained in part from my attached reprint, and from the National Research Council report of the symposium held last November. I am sure this material is now available to you.

The foreign developments in desalting of water in special fields of application are proceeding with usual European and Asiatic caution. My experience as science attaché in the American Embassy, London, revealed to me that we, as Americans, will always be accused by Europeans of appropriating their fundamental research findings and putting them in operation in the United States before they get around to it in Great Britain or the Continent. Personally, I think this is an admirable trait of the American free-enterprise system. My observation is that the Interior Office is "watchdogging" the foreign research of Europe and Asia in desalting of water most admirably, then passing this information on to their American contractors working under the saline-water program.

Kindly let me know if I can be of further assistance.

Sincerely yours,

W. R. WOOLRICH,
*Dean of Engineering.*

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[Refrigerating Engineering, February 1958]

POTABLE WATER FROM SALINE SOURCES—A REFRIGERATION OPPORTUNITY

W. R. Woolrich,[1] member, ASRE

For the past half century, manufacturers of ice in 300-pound blocks have eliminated successfully chlorine and other impurities normally found in municipal water supplies by the can-freezing process. Usually, this is done by agitating the freezing water by air turbulence to obtain a rejection of such impurities to the center core of unfrozen water, then subsequently removing this core of concentrated impurities and refilling this core cavity with clear water for final freezing.

The national research program of saline-water conversion of the United States Department of the Interior is authorized and devoted to providing potable, indus-

[1] Dr. Woolrich is dean of the College of Engineering, University of Texas. Previous related reports in Refrigerating Engineering have included: Desalting Sea Water by Freezing, July 1954, p. 44, and Fresh Water Extracted From Salt Water, September 1955, p. 45.

trial, and irrigation water from sea or brackish supplies. The objective is to develop new usable water supplies for these fields of application from our inexhaustible reservoirs of sea and brackish sources.

The United States Public Health Service drinking-water standard established in 1946 states: "The total solids should not exceed 500 parts per million for a water of good chemical quality. However, if such water is not available, a total solids contents of 1,000 parts per million may be permitted." Five hundred parts per million is approximately 29½ grains, and 1,000 parts per million is 59 grains per gallon of dissolved impurities.

Most of our American cities maintain a water supply between 6 and 18 grains per gallon or under 300 parts per million.

Sea-water salinity and inherent impurities usually correspond to 2,060 grains per gallon or 34,000 parts per million. One thousand gallons or 8,570 pounds of sea water will contain approximately 300 pounds of dissolved solids and 8,270 pounds of pure water. At greater depths, the salinity of sea water rises, the increase depending somewhat on the subsurface ocean currents. Some heart specialists object to their patients drinking water containing more than 3 or 4 grains per gallon of salt in water.

For industrial use, 60 grains per gallon of total solids is generally considered the upper practical limit. Even with this grade of water, a large number of American industries will treat a portion of their water by some softening method within their own plant prior for use in their boilers or their chemical processes. There are, of course, many industries such as those for the manufacture of rayon, paper, and textiles that will require an extremely low percentage of dissolved solids in the water to be used.

For agriculture purposes not only the salinity but the percentage of other chemicals, such as boron, is highly significant and may even, in small traces, make the water toxic to some crops.

The top impurities in sea water account for 299.8 pounds of the total 300 pounds of dissolved solids in each 1,000 gallons. The top 10 include sodium, chlorine, magnesium, calcium, potassium, bromine, and strontium. These seven all present some possibilities for their recovery for by-product commercial use to help carry the cost of the water treatment.

Irrigation alone will require approximately 1 billion gallons of water per day for the irrigation of each plot 20 miles square on the basis of supplying 1 inch of water per week to the irrigation of the 400 square miles or 256,000 acres of land within the plot.

In contradistinction to these large amounts needed in some fields of application there are many examples in the world where a relatively small plant processing water from a brackish well will be in demand by a village, a processor, or a stock raiser. In areas not far inland from the gulf coast it is not uncommon for the ground water level to drop significantly seasonally and the water to become too brackish for stock watering for some manufacturing processes. These widely varying applications will require further investigation as to the adaptability of available desalting methods for small as well as large installations.

Again, on the high plains of the United States, the drawing down of irrigation wells is sometimes followed by an increase in the saline solids in the pumped water. This brackishness may increase above the tolerance of the field and vegetable crops. The procedure to reduce the saline content to known plant tolerance may be greatly simplified for such service as against municipal use.

The overall cost goal of treated saline water set up by the Saline Water Office of the United States Department of the Interior for municipal water was $0.38 per 1,000 gallons. This cost is computed on a standard formula of all desalting methods to be compared.

Most of the methods under the present state of the art of desalting sea water will cost by this formula between $1.20 and $2 per 1,000 gallons of sea water demineralized. The research and development program of the United States looks forward to bringing most of these methods closer to the initial goal to give them greater public acceptance and general economic utility.

While there are many potential possibilities and unproven methods that are scientifically feasible for the demineralization of saline water, the conversion processes currently receiving the greatest attention in the United States are those classified as (1) distillation, (2) membrane, and (3) freezing procedures.

European scientists have done some effective work in desalting water and have cooperated with the United States in their research programs. In 1951 the

working party of the Office of European Economic Cooperation on Desalting of Brackish Water was called together at the suggestion of the Dutch delegation to consider the proposal of the Dutch that they investigate electrodialysis and that this might form a cooperative program with other member countries. The working party began by considering the desalting problem as a whole and also other processes which they regarded as having some promise including distillation at the critical pressure; separation by freezing; electrodialysis; vapor compression distillation; ion exchange; and distillation with solar energy.

A subsequent report of this original working party reflects an assessment of these processes as a basis for cooperative research endeavor. This report classified distillation at the critical pressure too improbable at the present time and desalting by freezing ruled out as probably uneconomic. The high cost of power in Western Europe was probably the determining factor in ruling the freezing method as of little promise in the regions under consideration.

To justify the use of the freezing process to provide potable, industrial and irrigation water from saline sources in any part of the world the methods must be competitively adapted to the use contemplated in preference to other processes which are available or proposed.

Although the working party of the Office of European Economic Cooperation put aside the freezing process of saline water conversion as unsuitable for their needs, however the United States has not been alone in the quest for a freezing method of producing a potable water from brackish or sea water supplies. As early as 1945, Italy under the leadership of E. Vacino and B. Visintin reported experiments in slushy ice-brine mixtures obtained by an oscillatory scrapping of refrigerated pipes in contact with sea water. They experimented with both gravitational and centrifugal separation of the pure water ice crystals from the mother solution.

Germany was the seat of work by A. Steinbach and N. Nesselman and reported the same in 1951. They froze saline water solutions in the form of hollow cylinders and slush then used several combinations of washing and centrifugating to separate the ice crystals from the concentrated solution.

More recently Japan has been making some extensive investigations on producing potable water from high concentrations of sea water. Japan must import salt and thus they approach the desalting problem with the intent of producing potable water as a byproduct recovery of the salt industry.

Jewish scientists working both in the United States and in Israel have been giving much time and effort to obtain a low-cost supply of irrigation water from the Mediterranean to make the reclamation of their arid areas possible. The freezing method is high on their rating but up to the present time their method is a secret process.

The panel of research investigators reporting on the freezing processes of saline water demineralization at the symposium on saline water conversion sponsored by the Office of Saline Water Conversion of the United States Department of the Interior and the National Research Council of the National Academy of Sciences were convinced that the freezing method of desalting had certain inherent advantages in the separation of salts and other impurities from water. Thermodynamically, freezing has a distinctive advantage over distillation methods. To vaporize a pound of steam from sea water requires nearly 1,000 B. t. u. To freeze a pound of ice from sea water at 26° or 27° F. requires about 150 B. t. u.

However, traditional freezing methods of producing commercial ice even with power estimates as low as 4 mills per kilowatt-hour would not be economically acceptable for most users. The economic feasibility of the freezing systems of producing potable water from the sea demands a system cycle that will conserve much of the energy originally required to produce the initial ice for other stages of the process. The power item alone would exceed the goal set out by the Office of Saline Water of the United States Department of the Interior of 38 cents per 1,000 gallons of potable water produced if conventional ice production methods were used.

The cycle that has been developed by the Carrier Corp. and reported to this current symposium on saline water conversion by Messrs. Carl Ashley and Cyrus M. Bosworth seems to be one answer in solving the problem of energy utilization as well as effective separation of the ice crystals from the mother saline solution. If further pilot plant studies confirm their laboratory findings for both the economic and the separation efficiency of the system, the available distillation and the membrane processes of sea water conversion will face an effective competitor. This will be on the basis of total costs per 1,000 gallons

processed, based on the Office of Saline Water conversion formula, which includes equipment amortization, power costs, maintenance, operation, obsolescences, and separation efficiency.

Other reports to the saline water symposium were by Prof. W. M. Hendrickson with R. F. Moulton and Thomas G. Thompson, H. L. Goering, and R. C. Himes of Battelle Memorial Institute, H. F. Wiegandt of Cornell University, Arthur Rose and A. W. Hutchison of Applied Science Laboratories, and Brother Henry Curran of the University of St. Edwards. Their combined impact on the symposium was best summarized by one observer in his remark after listening to the entire program: "Those freezing process researchers have something."

Not all of the research that is going on in the United States on the freezing processes of converting sea water for potable use is confined to the Office of Saline Water of the USDI. The American Society of Refrigerating Engineers is supporting a research study by Mr. O. G. Brown and Mr. Joe Bruns at the University of Texas on the Specific Heat of Ocean Water in the freezing range. Other universities report some activity in this field and express new interest in the possibilities of the processes.

Col. Crosby Field, president of the Flakice Corp. has probably had more experience with the rapid freezing of both fresh and saline water ice than any other living person. He is now giving the attention to the conversion of sea water which he gave previously to the perfection of uniformly constituted sea water ice for the marine products fishermen. With the vast fund of experience and scient fic research data on both sodium chloride solutions and normal sea water available to Colonel Field and his organization, new procedures for the economical production of potable water from saline sources can be anticipated from his personal laboratory.

Potable and usable water will ever be the most important single item in our national and international economy. With the world efforts pointed toward a more permanent peace as between peoples and races, the world population will continue to multiply at an unprecedented rate. In some areas of the world there is still an ample margin of run-off water that can be captured by conservation methods for human, industrial and agricultural use. But there are other areas within the United States where that margin of water available for human use is much too narrow. In 1956, 1 of 4 families in the United States experienced a water shortage. The human family is at the threshold of taking on an alltime task of furnishing these new needs by assisting nature to provide this Nation and other water-short peoples of the globe with great quantities of usable water for this and future generations from its unlimited supply—the sea.

We can anticipate that many refrigeration engineers of tomorrow will find themselves in the streamlines of this worldwide development. The anticipated quantities of water needed from these conversion processes run into astronomical figures, and it is not too early to predict that a fair share of the saline water processing of that tomorrow will be by the refrigeration method.

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UNIVERSITY OF WASHINGTON,
DEPARTMENT OF MECHANICAL ENGINEERING,
*Seattle, March 26, 1958.*

Subject: USDI saline-water-conversion program.

Mr. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee of the Committee on Government Operations, House Office Building, Washington, D. C.*

DEAR MR. JONES: We have been somewhat slow in answering your letter of February 20 on the above subject, first because our current file was mislaid for several weeks, and, second, because it is difficult for us to comment on the broad points outlined in your letter in view of the limited scope of [y]our investigations in the field. Our contract with the Office of Saline Water covered studies of purification of sea water by freezing methods. Our final design for a 10-million-gallon-per-day plant using conventional refrigerating equipment resulted in a cost of $2.31 per 1,000 gallons of potable water based on the Office of Saline Water standardized estimating procedure, as compared with $1.94 per 1,000 gallons for 12-effect flash distillation estimated on the same basis. These costs leave much room for improvement, but are realistic and include all normal business expense that would have to be taken into account in a private enterprise.

Regarding the five specific points outlined in your letter of February 20, our comments and impressions are as follows:

1. We believe the current state of progress is such that large-scale plants could be built to produce potable water at a cost of $1.50 to $2 per thousand gallons at the plant.

2. The coordination between the Office of Saline Water on the one hand, and private industry and colleges on the other, is excellent but there are just not enough people working on the problem.

3. The rate of progress should be accelerated both in basic and applied research if costs are to be reduced to 30 to 40 cents per thousand gallons of potable water in a reasonable time. If funds are limited, applied research should be emphasized though there is still a need for more basic research.

4. To hasten progress, more research-and-development contracts should be given to private industry. Specific basic and applied research problems of limited scope, suitable for thesis projects, should be outlined and sent around to all of our colleges and universities. A program of research grants should be set up to provide funds for the schools undertaking any of the proposed investigations. All of this will require larger appropriations to the Office of Saline Water to broaden the scope of all their investigations.

5. At this time we believe that distillation processes offer the best possibilities for low-cost saline-water conversion if the problems of scaling and corrosion can be solved satisfactorily. There is much need for research on and standardization of materials for use in heat exchanges and piping. Freezing processes should not be ruled out as the development of special cycles and new low-cost refrigeration machinery offer possibilities for reducing costs to a reasonable figure in due time. All of our estimates were based on a 10-million-gallon-per-day plant converting sea water at 30,000 parts per million salinity to potable water at 500 parts per million.

We trust that the foregoing comments and impressions will prove helpful in your study of the saline-water-conversion program, and apologize for being so slow in getting them to you.

Very truly yours,

H. M. HENDRICKSON, *Professor.*

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WESTINGHOUSE ELECTRIC CORP.,
*March 28, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee.*

DEAR MR. JONES: We are pleased to have the opportunity to outline our experience in the field of saline-water purification for the consideration of your committee.

A. WESTINGHOUSE EXPERIENCE

While we have not participated directly in the saline-water program sponsored by the Congress, we have followed these developments with keen interest. These research programs have been helpful in evaluating the various schemes for providing potable water and have created widespread interest in the purification of saline waters.

Westinghouse has been active in the field of sea-water distillation for many years, having installed a 720,000-gallon per day plant in Kuwait, Arabia, in 1950. This installation has been enlarged to 1 million gallons per day and continues to supply all the water requirements of the refinery and personnel of the Kuwait Oil Co.

This installation attracted widespread attention and the Ruler of Kuwait ordered a similar Westinghouse plant which was put in service in 1953. While these plants are satisfactory and are in full-time operation, it was apparent that design improvements were needed which would permit large unit capacities (the above installations consisted of multiple plants each of 120,000-gallon per day capacity) and reduce operating expenses.

During 1958, Westinghouse placed 4 multistage flash evaporator plants in operation in Kuwait. These units each produce 630,000 gallons per day of drinking water from high salt content Persian Gulf water. This installation has been in operation for several months and our experience indicates that we have successfully minimized two of the most troublesome problems normally associated with sea-water distillation, scaling, and corrosion.

Thus our experience confirms that of many other groups: Multiple-stage flash evaporators are today the most practical means of producing large quantities of potable water from full strength sea water.

### B. ECONOMICS

If one grants that flash distillation is a practical method for desalting sea water, it remains to be shown that it is an economic scheme. Distillation plants are installed in areas where fuel costs are appreciable as well as in regions where waste natural gas is available at essentially no cost. An evaluation of the cost of water from the installation in Kuwait was made by J. R. Emmett[1] of the consulting firm of Ewbank & Partners, London, as follows:

TABLE I

| Scheme | Fuel cost | Combined with power production | Dollars per 1,000 gallons |
|---|---|---|---|
| A | None | No | $0.63 |
| B | None | Yes | .37 |
| C | Yes [1] | No | 1.87 |
| D | Yes [1] | Yes | 1.61 |

[1] Based on oil, at $2.40 per barrel.

The above data show that the cost of water produced varies over a wide range depending on the assumptions for fuel costs and the possibilities of combining power production with distillation. It should be noted that the 4-stage design is poorly suited for use with expensive fuel; the fuel cost shown would result in an 8- to 12-stage design.

We have recently evaluated a 10-million gallon per day 8-stage plant using the procedure established by the Interior Department.[2] The plant studied was a well-defined extension of our Kuwait experience and is therefore, based upon sound estimates. The total capital cost including site, boiler plant, and all services was approximately $18 million and the total cost of water was $1.13 per 1,000 gallons. This does not include the production of byproduct power, which in past estimates has resulted in a reduction of approximately 30 percent in water costs or a value of $0.79 per 1,000 gallons, including byproduct power.

It should be noted that this method includes a fuel cost of 25 cents per million B. t. u.'s, while in table I the fuel cost was 47 cents per million B. t. u.' s.

Since these costs are well above the goals established by the Interior Department for practical, economical systems, one might inquire to what the future developments in the field may achieve. The design changes between our Kuwait installations in 1953 and those in 1957 resulted in a reduction in total plant costs of approximately 40 percent. Further substantial improvements can be achieved by increasing the temperature range of the evaporators and by utilizing lower cost materials.

### SUMMARY AND RECOMMENDATIONS

1. Our experience indicates that multistage flash evaporator plants are now economic in many areas and further developments should broaden their areas of application.

2. We would propose that a multistage flash evaporator demonstration plant of moderate size (100,000 to 500,000 gallons per day) be constructed on the coast of the United States or in the Virgin Islands to evaluate costs and to further develop the art of flash evaporation under field conditions. A further advantage of such a demonstration plant would be to acquaint potential users with the practical details of operating such a plant.

Very truly yours,

R. L. COIT,

*Manager, Development and Application Section, Heat Transfer Applied Engineering Department.*

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[1] Emmett, J. R., Practical Methods for the Purification of Saline and Brackish Waters, presented in London, 1957.

[2] Office of Saline Water, U. S. Department of the Interior, A Standardized Procedure for Estimating Costs of Saline Water Conversion, March 1956.

WHITING CORP.,
*Harvey, Ill., March 4, 1958.*

Hon. ROBERT E. JONES,
*House of Representatives, Washington, D. C.*

DEAR SIR: In your letter of February 24, 1958, you asked a series of questions pertaining to the saline-water-conversion program, particularly with respect to our part in the research and development. I shall attempt to answer your questions in sequence to the best of my ability.

1. You requested information as to the current state of progress, both here and abroad, in the saline-water program. A great deal has been written on this subject, and I suspect the Office of Saline Water has already supplied you with the information we have available. In general, the problem appears to vary according to the area. Where saline waters having a relatively low solids content are available, processing devices such as the electric-membrane system appear to have application, whereas in areas having access only to sea water with its relatively heavy concentration of solids, other processes such as multiple-effect evaporation are more applicable. This is again modified by the availability of fuel and the distribution system. For example, in Australia where fuel is not readily available to remote inland areas, solar evaporation appears to be one of the most feasible approaches, the same being true of some of the Mediterranean areas where the individual output requirements are relatively small. Thus, before a detailed answer can be given to this particular inquiry, various conditions indicated above should be defined.

2. With regard to the extent of coordination between the Federal Government, private industry, and other public and private groups, both here and abroad, there have been to my knowledge a number of meetings and symposiums held on the subject in many locations. The interchange of technical information appears to be normal and reasonably satisfactory. Since the problem varies from one area to another, the value of research conducted in one location is not always of value to individuals in another area. In my opinion, our Government and the Department of the Interior have made an outstanding contribution to saline-water conversion and are continuing to do so. The degree of coordination between the Federal Government and private industry in the United States has reached an unusually high level in this endeavor as well as an unusually high order of effectiveness at minimum expense. This is due in no small part to the careful and realistic approach adopted by the Office of Saline Water Conversion. With the possible exception of appropriation of additional funds, it is not believed that present conditions could be greatly improved in this regard.

3. The proper division of funds between basic and applied research is a question which has plagued industrial directors of research for years. The development program in which we are currently cooperating with the Department of the Interior could properly be termed engineering application of known processes since the number of unknowns in the entire proposal are in comparison with other proposals at a minimum. Nevertheless, basic research is required to develop means for preventing the formation of scale and for minimizing corrosion rates. I could conscientiously recommend the expenditure of funds for a basic study of the mechanism of scale formation, since the results in such a study would have wide applicability both to industry and the armed services. To whatever extent it may serve as a guide to your committee, a rule sometimes applied in industrial research organizations of larger companies is to spend approximately 10 percent on basic research, the balance being devoted to applied research or engineering applications. Whether limited funds in this instance should be devoted to basic research or to engineering application is governed in large measure by the urgency assigned to the problem as well as by the likelihood of successful completion within a reasonable length of time. Since it is my understanding that immediate results are urgently required in many areas, the application of a majority of the funds to engineering applications appears to be indicated.

4. To a limited degree, an increase in the available funds could accelerate the programs now underway. It must be realized, particularly in research, that instances are encountered where the appropriation of additional funds would have little, if any, effect on the time required to reach a satisfactory conclusion. In this instance, however, since there are processes under ex-

amination which are apparently reasonably close to successful conclusion, the availability of additional funds might very well save considerable time. More specifically, engineering work for larger scale units could be started at this time and final engineering completed when test results are available.

5. I do not feel competent to advise you relative to costs, quantities, and other details in processes other than that in which we are immediately engaged, namely multiple-effect evaporation. To my knowledge however, the Office of Saline Water has estimates which should provide the best information available on these various proposals. Specifically with regard to multiple-effect saline-water-evaporation plants, I am attaching a series of self-explanatory tables which show clearly each item of cost recognized in the computation of costs as well as the exact values assigned in each instance. These exhibits also answer your inquiry as to the quantity of water to be converted per day. In general, these tables contemplate the erection of a plant having a production rate of approximately 17 million gallons per day of fresh water from full strength sea water carrying approximately 35,000 parts per million of solids. In this process, the salinity of the water has practically no effect on the plant or the cost and can be utilized with even the most brackish water. The output of the plant will be potable water of virtually any degree of hardness desired. Since the water is purified by distillation, it is quite possible that a small amount of sea water may be added to the output of the plant to provide some mineral content and thereby increase its potability. Your attention is particularly directed to the fact that water produced by multiple-effect distillation operating in conjunction with a power-generating plant offers the lowest projected cost. It is believed that ultimately the water resources of the United States, and particularly in the coastal cities, can be benefited greatly by combining the production of fresh water with the production of electric power and further that this objective can quite possibly be eventually attained without major financial effort on the part of the Government.

Insofar as we know at this moment, multiple-effect distillation offers the best available answer to the problem of providing fresh water, fit for human consumption, from sea water. Test work currently in process at Harbor Island, N. C., under contract from the Department of the Interior has shown very promising results to date and will quite probably be completed this calendar year. Since the results to date are favorable, it would quite possibly be desirable to initiate at this time engineering work on an intermediate-size plant having a capacity of perhaps 1 million gallons of fresh water per day which could serve as a pilot plant for the larger production unit to be built at a later date. Although it will not be possible to realize the low costs projected for the larger scale plant, it should not be assumed that this pilot plant cannot serve a highly useful purpose. It is believed there are a number of communities having access to ocean water requiring additional fresh-water supplies of this order of magnitude. It is believed that the interests of the people of the United States would be best served through the provision of funds sufficient to carry this project forward without delay and that considerable time can be saved by anticipating the results to be obtained and confirmed by experimental work now in progress.

I am sure you will appreciate the difficulty of incorporating in a letter of this nature all of the information available to us on a subject so extensive. If we have failed to provide any specific information which would be of value to your committee, please advise me of the omission and we will make every effort to obtain the data requested.

Very truly yours,

W. A. MOREY,
*Vice President (Engineering).*

TABLE I.—*Cost standards*

Annual charges:
- Interest: 3 percent of total capital
- Insurance: 1 percent of total capital
- Depreciation: 5 percent of total capital
- Maintenance: 3 percent of installed equipment cost

Operating charges:
- Labor: $2.50 per man-hour
- Fuel (as fired): $0.30 per million B. t. u.

Operating time: 8,300 hours per year (20 days' downtime)

TABLE II.—*Capital cost of 18,170 acre-feet per year 12-effect evaporation plant using 212° F. exhaust steam from 60-megawatt powerplant*

| | |
|---|---|
| Evaporators (2 sets) (installed) | $3,695,000 |
| Heat exchangers (installed) | 455,000 |
| Condensers and auxiliaries (installed | 300,000 |
| Pumps (installed) | 136,000 |
| Piping (installed) | 214,000 |
| Instruments (installed) | 35,000 |
| Total installed process equipment | 4,835,000 |
| Site development | 40,000 |
| Additions to powerplant service facilities | 65,000 |
| Weatherproofing | 240,000 |
| Engineering | 385,000 |
| Contingencies | 485,000 |
| Total plant cost (or $322 per annual acre-foot) | 6,050,000 |

TABLE III.—*Annual operating cost of 18,170 acre-feet per year 12-effect evaporation plant using 212° F. exhaust steam from 60-megawatt powerplant*

| | |
|---|---|
| Interest, 3 percent of total capital | $182,000 |
| Insurance, 1 percent of total capital | 60,000 |
| Depreciation, 5 percent of total capital | 303,000 |
| Maintenance, 3 percent of equipment cost | 145,000 |
| Labor, $2.50 per man-hour | 86,000 |
| Power, 5.16 mills per kilowatt-hour | 54,000 |
| Steam, $0.1218 per million B. t. u | 554,000 |
| Total (or $75.90 per acre-foot; or $0.233 per thousand gallons) | 1,384,000 |

TABLE IV.—*Capital cost of 18,650 acre-feet per year combination thermocompression 10-effect sea-water-evaporation plant*

| | |
|---|---|
| Boiler (installed) | $1,020,000 |
| Turbine, generator (installed) | 170,000 |
| Turbine, vapor compressor (installed) | 925,000 |
| Evaporators (installed) | 2,425,000 |
| Heat exchangers (installed) | 991,000 |
| Pumps (installed) | 138,000 |
| Piping (installed) | 305,000 |
| Instruments (installed) | 40,000 |
| Total installed process equipment | 6,014,000 |
| Site development | 70,000 |
| Office, shop, and lab | 135,000 |
| Weatherproofing | 300,000 |
| Engineering | 481,000 |
| Contingencies | 600,000 |
| Total plant cost (or $407.50 per annual acre-foot) | 7,600,000 |

FIGURE 3.—EFFECT OF TURBINE EXHAUST TEMPERATURE ON COST OF HEAT

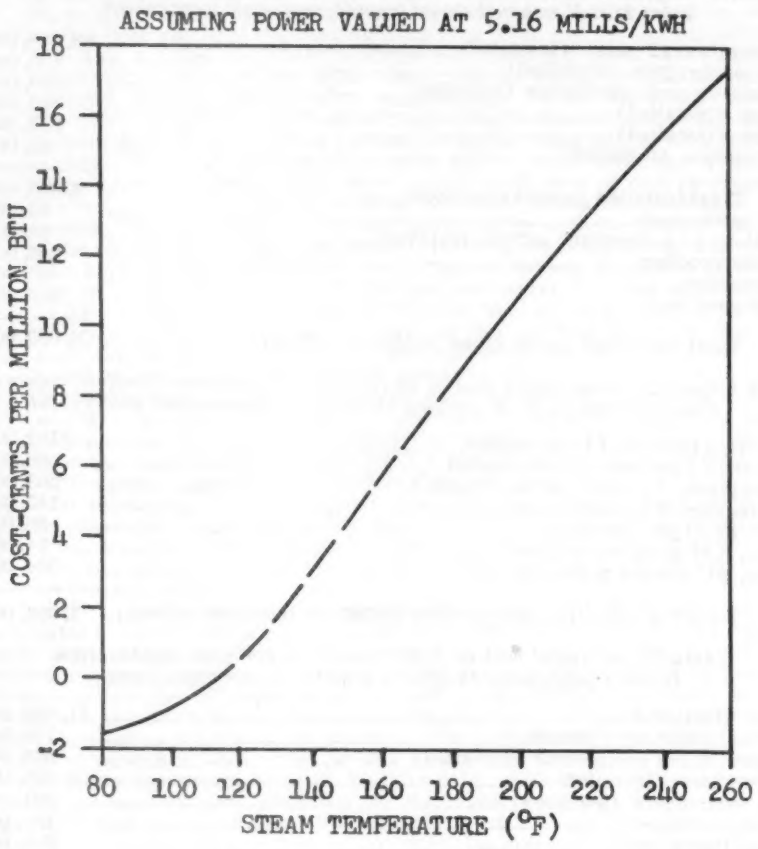

FIGURE 6.—EFFECT OF POWER VALUE AND STEAM TEMPERATURE ON MINIMUM WATER COST

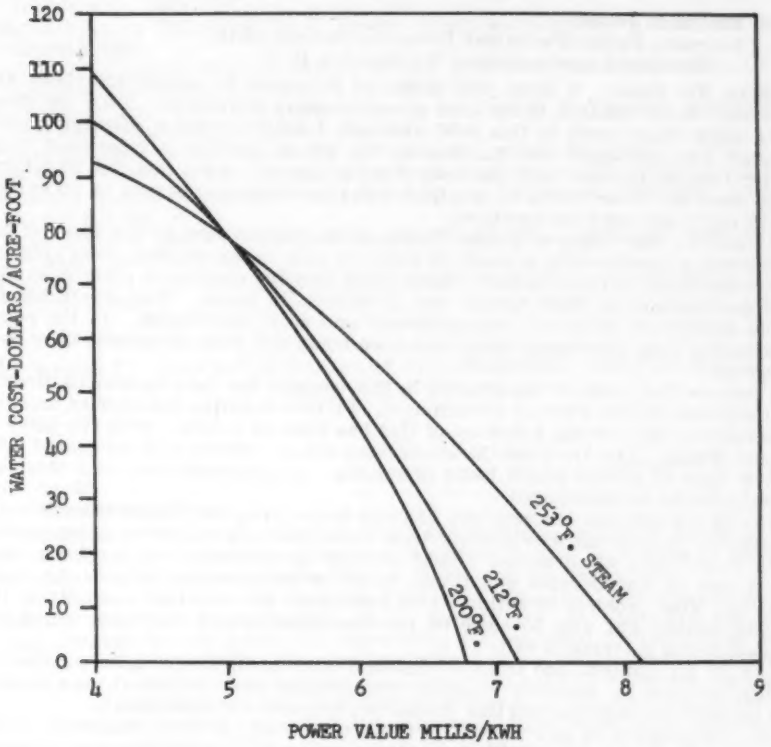


TABLE V.—*Annual operating cost of 18,650 acre-feet per year combination thermocompression 10-effect sea-water-evaporation plant*

| | |
|---|---|
| Interest, 3 percent of total capital | $228, 000 |
| Insurance, 1 percent of total capital | 76, 000 |
| Depreciation, 5 percent of total capital | 380, 000 |
| Maintenance, 3 percent of equipment cost | 180, 000 |
| Labor, $2.50 per man-hour | 138, 000 |
| Fuel, $0.30 per million B. t. u | 991, 000 |
| Total (or $106.90 per acre-foot; $0.328 per thousand gallons) | 1, 993, 000 |

THE UNIVERSITY OF WISCONSIN,
*Madison, March 5, 1958.*

Hon. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*House of Representatives, Washington, D. C.*

DEAR MR. JONES: I have your letter of February 21 asking for views and information on research in the field of saline water conversion. I am not doing very much direct work in this field, although I did supervise a research project 5 years ago and again last summer on the use of plastics in recovering fresh water from salt water with the help of solar energy. I am familiar in general with some of the activities in this field, but I certainly do not pose as an expert. I will try to answer your questions.

(1 and 2) The Office of Saline Water in the Department of the Interior has sponsored a considerable amount of research and, in my opinion, good progress has been made in this country. Some work is going on also in other countries and particularly in East Africa, and, I believe, in Israel. The researches include distillation of water, ion exchange, and solar distillation. In the solar-distillation field, laboratory tests have been made and pilot plant tests have been proposed.

I believe that most of the activity in this country has been sponsored directly or indirectly by the Federal Government. Private industry has carried on some experiments and testing, but some of this has been on contract with the Office of Saline Water. The Du Pont Co. is carrying out an extensive development with a new type of plastic which looks promising. A large-scale test with this new plastic should be encouraged.

(3) In my opinion, the recovery of fresh water from salt water is sufficiently important to warrant accelerating both basic research and pilot plant testing with engineering applications. Some of these applications will involve a pilot plant test of considerable magnitude, in order to properly evaluate the possibilities. This problem of saline water conversion is important not only to the United States, but also to some of the nonindustrialized countries which the United States is trying to help.

(4) In my opinion, the Office of Saline Water in the Department of the Interior, through its research contracts and general encouragement, has carried out an effective program and this should be continued and enlarged.

(5) The aspect of salt water conversion with which I am particularly familiar is that of solar distillation. Data are available for the cost of solar distillation using glass plates, but I believe that the replacement of glass plates by the new types of plastic should be emphasized. I believe that it is important to carry out pilot plant tests with these plastics in order to get cost estimates. In the solar-distillation method, sea water can be used as well as brackish water which contains only a small amount of salt. Other methods such as the ion exchange method are much easier to operate with brackish water than with sea water. I am not close enough to the research program to give estimates of the cost of producing fresh water. I doubt that any process will be able to compete economically with cheap irrigation water. This cost factor, however, should not prevent intensive research and development because there are special demands for fresh water which can afford to pay considerably more than the cost of irrigation water.

Sincerely yours,

FARRINGTON DANIELS,
*Chairman, Department of Chemistry.*

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(Additional responses to the subcommittee chairman's letters of inquiry are listed below. These letters are available in the files of the subcommittee):

Asiatic Petroleum Corp., signed by J. I. Bott, March 3, 1958.
Cornell University, signed by John W. Hastie, coordinator of research, March 7, 1958.
Florida, University of, signed by C. E. Reid, associate professor of chemistry, March 3, 1958.
Griscom-Russell Co., signed by Kenneth B. Ris, president, March 14, 1958.

Iowa State University, signed by Karl Kammermeyer, head of chemical engineering department, February 26, 1958.
Johns Hopkins University, The, signed by Abel Wolman, consulting engineer, February 24, 1958.
Maxim-Silencer Co., signed by C. Foster Harry, secretary and general manager, March 3, 1958.
National Aluminate Corp., signed by Walter M. Hertel, vice president, and F. K. Lindsay, assistant vice president, April 9, 1958.
Polytechnic Institute of Brooklyn, signed by Donald F. Othmer, professor of chemical engineering, February 25, 1958.
Power Generators, Inc., signed by A. J. Larrecq, president, April 1, 1958.
Resources Research, Inc., signed by Louis C. McCabe, president, March 25, 1958.
Southern Research Institute, signed by Locke White, Jr., assistant director, March 7, 1958.
Texas Electric Service Co., signed by J. B. Thomas, president and general manager, March 11, 1958.
Virginia, University of, signed by Prof. Frederick T. Morse, consulting engineer, March 3, 1958.

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## APPENDIX C—OTHER INQUIRIES BY THE SUBCOMMITTEE CHAIRMAN AND RESPONSES THERETO

### ITEM 1

FEBRUARY 10, 1958.

IONICS, INC.,
*Cambridge, Mass.*

GENTLEMEN: The Public Works and Resources Subcommittee of the Committee on Government Operations, House of Representatives, is making a study of the saline-water program in the United States and its possessions.

We understand that the Bahrein Petroleum Co., Ltd., operates an electrodialysis plant of approximately 86,400 gallons per day capacity for water demineralization. It would be appreciated if you could provide to us actual operating data concerning that and any other large-scale plants including plant investment, costs of operation, and maintenance, salinity of water, gallons of water demineralized per day, numbers of persons served, and any other data that might be helpful in informing this committee concerning actual costs operating conditions. The committee does have a copy of the Research and Development Program Report No. 11 of the Office of Saline Water (December 1956) prepared by your company, entitled, "Design, Construction, Field Testing, and Cost Analysis of an Experimental Electrodialysis Demineralizer for Brackish Waters."

Your cooperation in this matter will be appreciated.

Sincerely yours,

ROBERT E. JONES, *Member of Congress,*
*Chairman, Public Works and Resources Subcommittee.*

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IONICS, INC.,
*Cambridge, Mass., February 20, 1958.*

ROBERT E. JONES, *Member of Congress,*
*Chairman, Public Works and Resources Subcommittee,*
*Committee on Government Operations, Washington, D. C.*

DEAR CONGRESSMAN JONES: Your letter of February 10 has been received and we are in the process of preparing the operating data you have requested.

The Bahrein Petroleum Co. plant, rated at 86,400 gallons per day, is the largest plant we have sold to date. As will be indicated in our following letter, the installation costs of this plant are unusually high due to decisions made by the company to completely rebuild the building which houses the Ionics unit.

Although Ionics is the only company in the world which has successfully built and has operating electrodialysis plants for the demineralization of water, virtually all of the units sold to date are much smaller than the Bahrein plant. These units, numbering 22, have, however, accumulated more than 75 million membrane hours of operating life, and we feel this gives us a solid basis for the

claim that our unit is the only new and proven process for economically demineralizing brackish water developed during the past 10 years.

We carefully draw the distinction between demineralizing brackish and sea water inasmuch as the Ionics unit removes the salt from the water, whereas distillation removes the water from the salt. Hence the higher the salt content, the more work the Ionics unit has to do, with the resultant higher power cost and lower product volume per unit of feed.

There are vast land areas of the world underlain with brackish water containing from 2,000 to 10,000 parts of salts per million parts of water. Even along coastal areas, wells drilled a short distance back from the ocean will produce brackish water. These are the areas and places where the Ionics membrane plants can effectively operate, and where a large segment of the world's population and industry need potable water. We believe no other type of demineralizing equipment can compete with Ionics either on installation or operating costs when using brackish water for feed.

The lowest potential costs of installation and operation of Ionics equipment will never be demonstrated until a truly large scale plant is built. A plant of one and a half to two and a half million gallons a day capacity must be built to effect all the inherent economies of a large scale operation. For this size plant, engineering projections and cost data from Ionics plants now installed and operating, indicate installation costs of about $1 per gallon of capacity and operating costs of from 40 to 70 cents per thousand gallons depending upon the price of electricity and the salt content of the brackish feed water.

We very much appreciate your inquiry and welcome the opportunity to be of further assistance to you in your study of this tremendously important economic problem.

Sincerely yours,

WAYNE P. BROBECK, *Vice President.*

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IONICS, INC.,
*Cambridge, Mass, March 5, 1958.*

ROBERT E. JONES, *Member of Congress,*
*Chairman, Public Works and Resources Subcommittee,*
*Committee on Government Operations, Washington, D. C.*

DEAR MR. CHAIRMAN: Our further reply to your letter of February 10 has been delayed while we endeavored to gather operating cost data on the Bahrein plant. What data we have has been unofficially given us or was obtained by our service engineers on their periodic visits to the plant. Since these costs were given to us in confidence, we suggest that a request for this information to the California Texas Oil Co., 380 Madison Avenue, New York 17, N. Y., by you would result in favorable consideration. For convenience, CalTex has a Washington representative, Col. E. P. Kavanaugh, suite 609–611, 1000 Connecticut Avenue NW., Washington 6, D. C.

With 22 plants sold and in operation, it may seem anomalous that we are unable to give you generalized operating data on them. The explanation is that all of our commercial-type units sold to date are overseas, where installation and operating costs would not be comparable to those obtained here in the United States. The cost data which CalTex could furnish you will not be comparable to that which would be experienced on a similar size plant here in the United States.

We would, for example, today quote a price of $200,000 on a duplicate 86,000-gallon-a-day plant for United States installation, including building, or approximately $2.35 per gallon of installed capacity. With membrane development work now underway, we estimate that in the very near future this same plant could be built for $145,000 or approximately $1.65 per gallon of installed capacity. We would estimate an operating cost of about 50 cents per 1,000 gallons using feed water of the same salinity as that at Bahrein.

As to a large municipal or industrial plant from 2 to 3 million gallons per day capacity, we estimate such a plant could be constructed for about $1 per gallon of installed capacity. Depending upon the salinity of the water and power costs at the site, we estimate the operating costs would range from a low of 40 cents for 1,000 gallons up to about 70 cents.

In April of this year our first domestic commercial unit will go into operation in a restaurant on the New York State Thruway. We are looking forward to this event as our first opportunity to get domestic cost data on an Ionics unit.

Our other units sold here in the United States are specially designed military-type units, operating and cost data on which we do not yet have available to us.

We very much appreciate your subsequent letter of February 25, and are happy to give you our comments on the five aspects of the saline water conversion problem. Our comments that follow are in the same numerical order as those of your February 25 letter:

1. In our view, the saline water conversion problem is not a single, but a dual problem, each aspect of which is equally important: conversion of abundant brackish water underlying huge inland areas both here and abroad, and conversion of sea water for coastal areas. If this geographical fact is accepted, then we feel progress on the solution to the brackish-water problem by the use of electrodialysis has advanced to the point where full-scale plants—2 to 3 million gallons a day—can and should be built here in the United States and overseas. As you know, a 3 million gallon a day electrodialysis plant is under construction in South Africa now. In fact, this size plant could have been built by the United States 2 years ago based upon the state of the art and engineering experience possessed at that time by Ionics.

The foreign development of electric membranes to be utilized in the South African plant was anticipated by several years by Ionics' basic work. These membranes will be manufactured and used, we believe, without recognition of our issued patents in that and other European countries. We can only conclude that the construction overseas of the first full-size electrodialysis plant is the direct result of failure to recognize the practical state of development of Ionics membranes 2 or more years ago by the Office of Saline Water. The loss of United States technological prestige by the South African plant announcement, as well as by a smaller plant to be installed by the English in Tobruk need not have happened. Ionics, at its own expense, air shipped a small unit to Libya and held a few demonstrations there late last year. Cooperation by United States—ICA personnel in further demonstration of this unit was practically nonexistent.

The ultimate economies of large capacity membrane plants can be realized only by actual construction, but one thing is certain, the more and the bigger the plants built, the lower the cost of water will be.

There are others, more competent than we, to comment on the progress being made on other types of equipment for conversion of saline water.

2. There has been, in Ionics' case, a degree of cooperation on the part of the Federal Government. Although our membranes and system were developed and patented prior to the establishment of the Office of Saline Water, that Office has contracted with Ionics for some development research in the past and did procure one of our early model units. Likewise, about 2 years ago the Navy bought experimental units for study of possible use on board submarines and shore installations to convert sea water.

Private industry, primarily overseas oil companies, have cooperated with Ionics to a much greater extent in that they bought equipment for use in their Middle East oil refinery communities, even though the Office of Saline Water had not and still has not rendered a final official evaluation of the equipment after 2½ years. Ionics was therefore interested in the first official statement on the subject made by Secretary of Interior Seaton in his news release of February 22, when he said in part "that electrodialysis using ion exchange membranes had become a commercial reality and that other membrane processes were ready for the pilot-plant phase." As the pioneers in this field, with the most experience and having built more units than anyone else, we have neither been consulted nor approached to build such a pilot plant. Ionics fails to comprehend the necessity of spending more money to try to develop a different type membrane, without first exhausting all the inherent possibilities of the electric membrane.

In summary, we feel the research stage on electric membranes has been completed; what is needed is Federal assistance to build big plants. The need to convert brackish water exists today both in the United States and in vital areas overseas. The Government can and should spearhead a program to make the process known and to assist in its exploitation. From an international standpoint, the English and South Africans have stolen a technological march on the United States in the eyes of the uncommitted people of the Middle East, and the Russians will not overlook this possibility either.

3. In the case of electric membrane equipment, we feel further research is unnecessary, and such funds as may be available should be channeled into the development, engineering and construction of large-scale demonstration plants both in the United States and abroad. Consideration should also be given to

the distribution of small, easily transported plants in the Mediterranean and Middle Eastern areas under ICA auspices.

There is an area of development which additional financial assistance may yield substantial returns, and that is in the use of membranes as a possible competitor to distillation equipment to convert sea water. In other words, there exists a possibility that the characteristics and efficiencies of future membranes could be such as to permit them to compete in total cost with the best of the heat systems, particularly if, as is generally known, the problem of scale formation is not solved without making distillation plants tremendously oversize to permit lower temperature operation.

Another area where more basic research should be financed is in freezing techniques. Ionics, for example, would be very much interested in studying the possibilities of a duplex system using freezing techniques to reduce sea water to brackish levels, and then process the brackish water through membrane equipment. Ionics has some interesting and original ideas on how this might be done.

Others can comment more competently on evaporation progress.

4. The Government can hasten progress by:

(*a*) Having a more definitive program provided for in its appropriation legislation language. In other words, the Office of Saline Water should prepare and defend specific categories of research and/or development projects having both money and time goals. The Office needs more personnel with high level technical competence for rapidly evaluating the results of its programs. It should also have a sense of urgency and desire to get programs out of the research stage and into production. This does not imply the need for many people with supporting administrative personnel.

(*b*) A clear, uniform, and reasonable patent policy as relates to the retention of patent rights by private industry where such exist independent of work performed under Government contracts.

(*c*) The Government should undertake a comprehensive survey of brackish water deposits throughout the United States, together with the compilation of a central source of information as to areas and towns where brackish water exists and is used. The Government could then make information available to these communities and industries in these areas, information on the latest developments and equipment.

5. For a 200,000 gallon per day plant, using feed water which contains 2,400 parts per million of total dissolved solids, producing water containing 500 parts per million, with electric power at 1 cent per kilowatt-hour, and an amortization period of 15 years, we estimate the following costs:

| | Case I | Case II |
|---|---|---|
| Investment in plant and building (not including land) | $232,000 | $192,000 |
| Operating costs (cents per thousand gallons): | | |
| Amortization (not including interest) | 21.0 | 12.2 |
| Membrane replacement (one-third per year) | 28.6 | 8.2 |
| Power | 7.2 | 8.7 |
| Direct operating labor | 5.7 | 3.5 |
| Miscellaneous | 2.4 | 2.0 |
| Total | 64.9 | 34.6 |

Case I above is the estimate based upon existing equipment.

Case II above is the estimate based upon improved equipment to be available within 18 months.

It should be kept in mind that as the salt content of feed water increases, the cost of power goes up and for a given size plant, the output decreases. It is also reasonably safe to assume that prices and costs would be lower after several big plants had been constructed.

The above-mentioned improved equipment in case II will be the result of company-sponsored development of larger and more efficient membranes. These results could be available much sooner if the Government desires to assist.

We would add one final observation about the specific water problem in the Virgin Islands. Last year, Ionics was consulted on the problem and, had an adequate source of brackish water been found there on St. Thomas, we feel sure

an Ionics plant could have paid for itself within 2 years from money saved by not having to barge water in from Puerto Rico. The well near the airport, however, would not pump 30,000 gallons per day for 30-day test period. Ionics believes that the well at Pearsons Gardens housing development might provide adequate brackish feed water if it could be made available. This matter could not be resolved further because of a jurisdictional problem alleged to exist between the Public Housing Authority and the island government.

Again it is our pleasure to be of assistance to you in this matter. This is a tremendously important problem, and we compliment you on the thorough manner in which you are proceeding.

If at any time we can be of assistance to you, please do not hesitate to call upon us.

Sincerely yours,

WAYNE P. BROBECK, *Vice President.*

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ITEM 2

FEBRUARY 11, 1958.

Dr. CHARLES W. THORNTHWAITE,
*Director, Laboratory of Climatology,*
*Centerton, N. J.*

DEAR DR. THORNTHWAITE: The Public Works and Resources Subcommittee of the Committee on Government Operations, House of Representatives, is engaged in a preliminary study of the Government's saline water conversion program, administered by the Department of the Interior.

We are gathering, as a background for this study, whatever information is available regarding saline water conversion programs of other organizations besides the Federal Government. We are especially interested in any cost data developed with respect to particular conversion processes. Hence, we are writing to you, as the United States member of the UNESCO Advisory Committee on Arid Zone Research, for information on any studies made, programs started, or data collected by UNESCO. We are also interested in information on studies or programs in this field initiated by foreign governments, particularly the U. S. S. R.

Next fall, we understand, there will be an international symposium in Teheran on salinity problems. We would be most interested to have additional information regarding this symposium, such as dates, sponsorship, and proposed agenda.

It would be greatly appreciated if you could furnish us, at your earliest convenience, whatever information you can on the above matters.

Sincerely yours,

ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee.*

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THE LABORATORY OF CLIMATOLOGY,
*Centerton, Elmer, N. J., February 14, 1958.*

Mr. ROBERT E. JONES,
*Chairman, Public Works and Resources Subcommittee,*
*Congress of the United States, House of Representatives,*
*Washington, D. C.*

DEAR MR. JONES: This is in reply to your letter of February 11 requesting information on the program of the UNESCO Advisory Committee on Arid Zone Research in the field of saline-water conversion.

The committee has been more interested in the utilization of saline water than in its conversion. The committee sponsored a symposium on arid zone hydrology in Ankara, Turkey, and published the proceedings in 1953. A review of research on problems of utilization of saline water was published in 1954.

At a meeting in 1957, the committee received from the Desert Institute of Israel a request, among others, for support of studies of water desalinization in the amount of $25,000. It recommended that the sum of $5,000 be granted for research on membranes for desalinization. In this same meeting, the com-

mittee approved the establishment of a subcommittee to guide the Secretariat in the establishment of an information center on the purification of saline water and to organize a symposium on salinity problems for 1958 in Iran. Dr. David S. Jenkins, director of the United States program, was named a member of this subcommittee, and he can give you detailed information on its activities. He probably is more up to date on progress of the symposium in Teheran than I am.

I recently received a memorandum from Mr. M. Batisse of the UNESCO Secretariat containing the following information:

"SYMPOSIUM ON SALINITY PROBLEMS IN ARID REGIONS

"This symposium will last for 5 days and will be devoted to the presentation and discussion of scientific papers arranged under the following sections:

"I. Hydrology with special reference to salinity (including artificial management of the hydrologic cycle to prevent salinification).

"II. Physiology of plants and animals in relation to consumption of saline water.

"III. Use of brackish water under irrigation (including special reference to saline soils).

"IV. Demineralization of saline water (vaporization using conventional fuels, freezing, solar distillation, osmosis, electrodialysis, chemical methods).

"Negotiations are proceeding with the Iranian Government on the symposium which is tentatively fixed from October 11 to 15, 1958. Invitations for the countries of the region stretching from north Africa ot India will be handled by the Iranian authorities and it will be our responsibility to invite 10 to 12 eminent specialists from outside this region, most of whom will be asked to prepare introductory papers for the various sections. In this connection I have been writing to Dr. Jenkins who has agreed to prepare an introductory paper for section IV and I am planning to write to Dr. Richards in Riverside to ask him whether he would accept to write one for either section II or section III. It is our understanding that the Iranian Government will see only advantages in a small number of qualified specialists from outside the region where they are launching their invitations, taking part in the symposium at their own or their Government's expense. The matter is not yet finalized and I will naturally let you know in due course of any developments."

It is clear to me that the UNESCO Committee will not in any way duplicate the work of the Office of Saline Water of the Department of the Interior. On the other hand, my observations in the arid areas of the world makes it clear to me that the program of the Interior Department is vitally important to our country and to the world. I hope that it can be greatly accelerated.

Sincerely yours,

C. W. THORNTHWAITE, *Director.*

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## EXHIBITS

### EXHIBIT 1

**Act of July 3, 1952 (66 Stat. 328, 42 U. S. C., secs. 1951 et seq.)**

PUBLIC LAW 448—82D CONGRESS

CHAPTER 568—2D SESSION

H. R. 6578

AN ACT To provide for research into and development of practical means for the economical production, from sea or other saline waters, of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses, and for other purposes

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That, in view of the acute shortage of water in the arid areas of the Nation and elsewhere and the excessive use of underground waters throughout the Nation, it is the policy of the Congress to provide for the development of practicable low-cost means of producing from sea water, or from other saline waters, water of a quality suitable for agriculture, industrial, municipal, and other beneficial consumptive uses on a scale sufficient

to determine the feasibility of the development of such production and distribution on a large-scale basis, for the purpose of conserving and increasing the water resources of the Nation.

SEC. 2. In order to carry out the purposes of this Act, the Secretary of the Interior, acting through such agencies of the Department of the Interior as he may deem appropriate, is authorized—

(a) by means of research grants and contracts as set forth in subsection (d) of this section to conduct research and technical development work, to make careful engineering studies to ascertain the lowest investment and operating costs, and to determine the best plant designs and conditions of operation;

(b) to study methods for the recovery and marketing of byproducts resulting from and incident to the production of water as herein provided for the purpose of ascertaining the possibilities of offsetting the costs of water production in any area by the commercial utilization of such products;

(c) to acquire, by purchase, license, lease, or donation, secret processes, technical data, inventions, patent applications, patents, licenses, land and any interest in land (including water rights, easements, and leasehold interests), plants and facilities, and other property or rights: *Provided*, That the land or other property acquired hereunder shall not exceed that necessary to carry on the experiments and demonstrations for the purposes herein provided;

(d) to engage, by noncompetitive contract or otherwise, chemists, physicists, engineers, and such other personnel as may be deemed necessary, and any educational institution, scientific organization, or industrial or engineering firm deemed suitable to do any part of the research or other work, and to the extent appropriate to correlate and coordinate the research and development work of such educational institutions, scientific organizations and industrial and engineering firms; and

(e) to cooperate with any other Federal, State, or municipal department, agency, or instrumentality, and with any private person, firm, educational institution, or other organization in effectuating the purpose of this Act.

SEC. 3. Research undertaken by the Secretary of the Interior under the authority contained in this Act shall be coordinated or conducted jointly with the Department of Defense to the greatest practicable extent compatible with military and security limitations, to the end that research and developments under this Act which are primarily of a civil nature will contribute to the defense of the Nation and that research and developments in the same field which are primarily of a military nature and are conducted by the Department of Defense will be made available to advance the purposes of this Act and to strengthen the civil economy of the Nation.

SEC. 4. The Secretary of the Interior is authorized, for the sole purpose of this Act, to dispose of all water and other products produced as a result of his operations under this Act pursuant to regulations to be prescribed by him: *Provided*, That nothing in this Act shall be construed to alter existing law with respect to the ownership and control of water.

SEC. 5. All moneys received for products of the plants under this Act shall be paid into the Treasury as miscellaneous receipts.

SEC. 6. The Secretary of the Interior shall make reports to the President and the Congress at the beginning of each regular session of the action taken or instituted by him under the provisions of this Act. The report shall include suitable recommendations for further legislation.

SEC. 7. The Secretary of the Interior may issue rules and regulations to effectuate the purposes of this Act.

SEC. 8. There are authorized to be appropriated, from any funds in the Treasury not otherwise appropriated, such sums, not to exceed $2,000,000, for a five-year period, to carry out the provisions of this Act: *Provided*, That departmental expenses for the correlation and coordination of information over such five-year period shall not exceed the sum of $500,000: *Provided further*, That such departmental expenses shall be scheduled in equal amounts for each year of such period insofar as practicable.

Approved July 3, 1952.

EXHIBIT 2

Act of June 29, 1955 (69 Stat. 198)

PUBLIC LAW 111—84TH CONGRESS

CHAPTER 227—1ST SESSION

H. R. 2126

AN ACT To amend the Act of July 3, 1952, relating to research in the development and utilization of saline waters

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That the Act of July 3, 1952 (66 Stat. 328; 42 U. S. C., secs. 1951 ff.), is hereby amended as follows:

(1) By modifying subsection (a) of section 2 of said Act so as to read: "by means of research grants and contracts as set forth in subsection (d) of this section and by use of the facilities of existing Federal scientific laboratories within the monetary limits set forth in section 8 of this Act, to conduct research and technical development work, to make careful engineering studies to ascertain the lowest investment and operating costs, and to determine the best plant designs and conditions of operation".

(2) By modifying section 3 of said Act to add the following: "Similarly, the fullest cooperation by and with the Atomic Energy Commission and the Civil Defense Administration in research shall be carried out in the interest of achieving the objectives of the program.".

(3) By modifying section 8 of said Act so as to read: "There are authorized to be appropriated such sums, but not more than $10,000,000 in all, as may be required (a) to carry out the provisions of this Act during the fiscal years 1953 to 1963, inclusive, (b) to finance for not more than two years beyond the end of said period such grants, contracts, cooperative agreements, and studies as may theretofore have been undertaken pursuant to this Act, and (c) during the same additional period plus one more year, to correlate, coordinate, and round out the results of studies and research undertaken pursuant to this Act. Departmental expenses for direction of the program authorized by this Act and for the correlation and coordination of information as provided in subsection (d) of its section 2 shall not exceed $2,000,000, and not more than $2,500,000 shall be expended for research and development in Federal laboratories. Both of said sums shall be scheduled for expenditure in equal annual amounts insofar as is practicable: *Provided*, That not to exceed 10 per centum of the funds available in any one year for research and development may be expended in cooperation with public or private agencies in foreign countries in the development of processes useful to the program in the United States: *And provided further*, That contracts or agreements made in pursuance of this proviso shall provide that the results or information developed in connection therewith shall be available without cost to the program in the United States herein authorized."

Approved June 29, 1955.

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EXHIBIT 3

STATEMENT OF THE MANAGERS ON THE PART OF THE HOUSE

(Statement of House Conferees accompanying the Conference Report of June 20, 1955 (H. Rept. 861, 84th Cong., 1st sess.), on H. R. 2126, to amend the act of July 3, 1952, relating to research in the development and utilization of saline waters)

The managers on the part of the House, at the conference on the disagreeing votes of the two Houses on the amendments of the Senate to the bill (H. R. 2126) to amend the act of July 3, 1952, relating to research in the development and utilization of saline waters, submit the following statement in explanation of the effect of the action agreed upon and recommended in the accompanying conference report:

The language agreed upon in the conference does not alter or change the basic purposes or provisions of the bill as passed by the House. The changes are in the amounts authorized to be appropriated and used for various purposes. The managers for the House agreed with the Senate position that national and international conditions require that the program be expedited and, therefore, the amount ($10 million) proposed by the Senate for the research program over the 13-year period is retained in the bill.

The Nation's rapidly increasing population and expanding industry, with the corresponding rapidly increasing needs for water, the critical water situations that have developed in many areas in recent years, and national and international conditions in this atomic age all reflect the imperative need for speeding the objectives of this program. It may become necessary within the term of this program for many areas to depend on salt or saline water conversion for a water supply. Ways and means must be found without undue delay for economically converting salt or saline water to fresh water. The program cannot be allowed to drift along without producing concrete results, and it is expected that with the expanded implementation of the saline-water program authorized by this legislation results will be obtained.

The language agreed upon in the conference specifically requires close cooperation and coordination of the saline-water research program with and by the Atomic Energy Commission and the Civil Defense Administration in the interest of achieving the objectives of the program. National and world conditions emphasize the desirability of tying the saline-water program in directly with the Atomic Energy and Civil Defense activities. Also, energy is a primary factor in the demineralization of saline water and atomic power may in the future be the answer to low-cost production of fresh water from salt or saline water.

CLAIR ENGLE,
WAYNE N. ASPINALL,
LEO W. O'BRIEN,
A. L. MILLER,
JOHN P. SAYLOR,
*Managers on the Part of the House.*

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EXHIBIT 4

THE WHITE HOUSE,
*Washington, March 16, 1950.*

The honorable the SECRETARY OF STATE:

MY DEAR MR. SECRETARY: At my request the Secretary of the Interior will seek the enactment of legislation authorizing him to perform the necessary research and development work for the production from sea water of water suitable for agricultural, industrial and other beneficial consumptive uses. Pending action by the Congress, I have directed the Secretary, within the limits of available staff and funds, to begin the collection of available information on past research and investigations by public agencies, industrial concerns, and educational institutions.

The Secretaries of Commerce, Defense, and Agriculture, the Federal Security Administrator, the General Services Administrator, and the Chairman of the Federal Power Commission have been requested to provide assistance to the Secretary of the Interior through prompt collection of pertinent materials

within their respective agencies and continuing cooperation in the analysis of data collected, as well as in whatever program may be authorized by the Congress.

Without doubt, individual scientists in the Federal agencies will know of work on the subject which has been done in other countries and will be able to establish productive, informal contacts with their colleagues around the world. I believe, however, that the importance of developing low-cost means for the conversion of sea water in large volume merits a formal proffer of collaboration from the United States and a request for such assistance and information on the investigations undertaken by other governments as they may be prepared to give. To this end, I shall appreciate it if you will confer with the Secretary of the Interior and obtain agreement upon the nature and kind of communication which is to go forward from the United States to other governments which you believe will have an interest in the problem. It is suggested that you use the United Nations and its related agencies to the extent deemed feasible.

Sincerely yours,

HARRY S. TRUMAN.

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EXHIBIT 5

THE WHITE HOUSE,
*Washington, March 16, 1950.*

The honorable the SECRETARY OF DEFENSE.

MY DEAR MR. SECRETARY: At my request the Secretary of the Interior will seek the enactment of legislation authorizing him to perform the necessary research and development work for the production from sea water of water suitable for agricultural, industrial, and other beneficial consumptive uses. Pending action by the Congress, I have directed the Secretary, within the limits of available staff and funds, to begin the collection of available information on past research and investigations by public agencies, industrial concerns, and educational institutions.

The large-scale conversion of salt water is a matter of interest to a number of Federal agencies, and I request that all of them cooperate as fully as possible with the Secretary of the Interior both in the collection of initial materials and in whatever continuing program may be authorized.

It is particularly important that information on the subject now available within your agency be brought together and supplied to the Secretary of the Interior promptly. I also request that full interagency cooperation and collaboration be maintained for the further analysis of such data when collected.

Similar letters are being sent to the Secretaries of Agriculture, and Commerce, the Administrators of the Federal Security Agency and the General Services Administration, and the Chairman of the Federal Power Commission. A letter regarding collection of information from foreign governments, a copy of which is enclosed, is being sent to the Secretary of State.

Sincerely yours,

HARRY S. TRUMAN.

Enclosure: Copy of letter to the Secretary of State.
(Identical letters sent to all those named in last paragraph of above letter.)

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EXHIBIT 6

[Vol. 3, Annals of Congress, P. 1042]

OBTAINING FRESH FROM SALT WATER

The SECRETARY OF STATE, to whom was referred by the House of Representatives of the United States, the petition of Jacob Isaacks, of Newport, in Rhode Island, has examined into the truth and importance of the allegations therein set forth, and makes thereon the following Report:

The petition sets forth, that, by various experiments, with considerable labor and expense, he has discovered a method of converting salt water into fresh, in the proportion of eight pints out of ten, by a process so simple that it may be performed on board of vessels at sea, by the common iron caboose (with small alteration), by the same fire and in the same time which is used for cooking the ship's provisions; and offers to convey to the Government of the United

States a faithful account of his art, or secret, to be used by or within the United States, on their giving to him a reward suitable to the importance of the discovery, and, in the opinion of Government, adequate to his expenses and the time he has devoted to the bringing it into effect.

In order to ascertain the merit of the petitioner's discovery, it becomes necessary to examine the advances already made in the art of converting salt water into fresh.

Lord Bacon, to whom the world is indebted for the first germs of so many branches of science, had observed, that, with a heat sufficient for distillation, salt will not rise in vapor, and that salt water distilled, is fresh. And it would seem that all mankind might have observed, that the earth is supplied with fresh water chiefly by exhalation from the sea, which is in fact an insensible distillation effected by the heat of the sun. Yet this, though the most obvious was not the first idea in the essays for converting salt water into fresh. Filtration was tried in vain, and congelation could be resorted to only in the coldest regions and seasons. In all the earlier trials by distillation, some mixture was thought necessary to aid the operation by a partial precipitation of the salt, and other foreign matters contained in sea water. Of this kind were the methods of Sir Richard Hawkins, in the sixteenth century; of Glauber, Hauton, and Lister, in the seventeenth century; and of Hales, Appleby, Butler, Chapman, Hoffman, and Dove, in the eighteenth century: nor was there anything in these methods worthy noting on the present occasion, except the very simple still, contrived extempore by Captain Chapman, and made from such materials as are to be found on board every ship, great or small. This was a common pot with a wooden lid of the usual form, in the centre of which a hole was bored to receive perpendicularly a short wooden tube, made with an inch and half auger, which perpendicular tube received at its top, and at an acute angle, another tube of wood also, which descended till it joined a third, of pewter, made by rolling up a dish, and passing it obliquely through a cask of cold water. With this simple machine he obtained two quarts of fresh water an hour, and observed, that the expense of fuel would be very trifling, if the still was contrived to stand on the fire along with the ship's boiler.

In 1762, Dr. Lind, proposing to make experiments of several different mixtures, first distilled rainwater, which he supposed would be the purest, and then sea water, without any mixture, which he expected would be the least pure, in order to arrange between these two supposed extremes the degree of merit of the several ingredients he meant to try. "To his great surprise," as he confesses, "the sea water, distilled without any mixture, was as pure as the rainwater." He pursued the discovery, and established the fact that a pure and potable fresh water may be obtained from salt water by simple distillation, without the aid of any mixture for fining or precipitating its foreign contents. In 1767, he proposed an extempore still, which, in fact, was Chapman's only substituting a gun barrel instead of Chapman's pewter tube, and the hand pump of the ship to be cut in two obliquely, and joined again at an acue angle, instead of Chapman's wooden tubes bored express; or, instead of the wooden lid and upright tube, he proposed a teakettle (without its lid or handle) to be turned bottom upward over the mouth of the pot, by way of still head and a wooden tube leading from the spout to a gun barrel passing through a cask of water, the whole luted with equal parts of chalk and meal moistened with salt water.

With this apparatus of a pot, teakettle, and gun barrel, the Dolphin, a twenty-gun ship, in her voyage round the world, in 1761, from fifty-six gallons of sea water, and with nine pounds of wood and sixty-nine pounds of pit-coal, made forty-two gallons of good fresh water, at the rate of eight gallons an hour. The Dorsetshire, in her passage from Gibraltar to Mahon, in 1769, made nineteen quarts of pure water in four hours, with ten pounds of wood. And the Slambal, in 1773, between Bombay and Bengal, with a hand pump, gun barrel, and a pot, of six-gallons of sea water made ten quarts of fresh water in three hours.

In 1771, Dr. Irvin, putting together Lind's idea of distilling without a mixture, Chapman's still, and Dr. Franklin's method of cooling by evaporation, obtained a premium of £5,000 from the British Parliament. He wet his tube constantly with a mop, instead of passing it through a cask of water. He enlarged its bore, also, in order to give it a freer passage to the vapor, and thereby increase its quantity by lessening the resistance or pressure on the evaporating surface. This last improvement was his own, and it doubtless contributed to the success

of his models; and we may suppose the enlargement of the tube to be useful to that point at which the central parts of the vapor, passing through it, would begin to escape condensation. Lord Mulgrave used his method in his voyage toward the North Pole, in 1773, making from thirty-four to forty gallons of fresh water a day, without any great addition of fuel as he says.

M. de Bougainville, in his voyage round the world, used, very successfully, a still which had been contrived in 1763, by Poyisonier, so as to guard against the water being thrown over from the boiler into the pipe by the agitation of the ship. In this, one singularity was that the furnace or firebox was in the middle of the boiler, so that the water surrounded it in contact. This still, however, was expensive, and occupied much room.

Such were the advances already made in the art of obtaining fresh from salt water, when Mr. Isaacks, the petitioner, suggested his discovery.

As the merit of this could be ascertained by experiment only, the Secretary of State asked the favor of Mr. Rittenhouse, President of the American Philosophical Society, of Dr. Wistar, President of Chemistry in the College of Philadelphia, and Dr. Hutchinson, Professor of Chemistry in the University of Pennsylvania, to be present at the experiments. Mr. Isaacks fixed the pot of a small caboose, with a tin cap and straight tube of tin passing obliquely through a cask of cold water; he made use of a mixture, the composition of which he did not explain, and from twenty-four pints of sea water, taken up about three miles out of the Capes of Delaware at floodtide, he distilled twenty-two pints of fresh water in four hours, with twenty pounds of seasoned pine, which was a little wetted by having lain in the rain.

In a second experiment, of the 21st of March, performed in a furnace and five gallon still at the College, from thirty-two pints of sea water he drew thirty-one pints of fresh water in seven hours and twenty-four minutes, with fifty-one pounds of hickory, which had been cut about six months. In order to decide whether Mr. Isaacks's mixture contributed in any and what degree to the success of the operation, it was thought proper to repeat his experiment under the same circumstances exactly, except the omission of the mixture. Accordingly, on the next day, the same quantity of sea water was put into the same still, the same furnace was used, and fuel from the same parcel. It yielded, as his had done, thirty-one pints of fresh water in eleven minutes more of time, and with ten pounds less of wood.

On the 24th of March, Mr. Isaacks performed a third experiment. For this, a common iron pot, of three and a half gallons, was fixed in brickwork, and the flue from the hearth wound once round the pot spirally, and then passed off up a chimney. The cap was of tin, and a straight tin tube of about two inches diameter, passing obliquely through a barrel of water, served instead of a worm. From sixteen pints of sea water he drew off fifteen pints of fresh water, in two hours and fifty-five minutes, with three pounds of dry hickory and eight pounds of seasoned pine. This experiment was also repeated the next day, with the same apparatus and fuel from the same parcel, but without the mixture. Sixteen pints of sea water yielded, in like manner, fifteen pints of fresh, in one minute more of time, and with half a pound less of wood. On the whole, it was evident that Mr. Isaack's mixture produced no advantage, either in the process or result of the distillation.

The distilled water in all these instances was found, on experiment, to be as pure as the best pump water of the city. Its taste, indeed, was not as agreeable, but it was not such as to produce any disgust. In fact we drink, in common life, in many places, and under many circumstances, and almost always at sea, a worse tasted and probably a less wholesome water.

The obtaining fresh from salt water, for ages was considered as an important desideratum for the use of navigators. The process for doing this by simple distillation is so efficacious, the erecting an extempore still with such utensils as are found on the board of every ship, is so practicable, as to authorize the assertion that this desideratum is satisfied to a very useful degree. But, though this has been done for upward of thirty years; though its reality has been established by the actual experience of several vessels which have had recourse to it, yet neither the fact nor process is known to the mass of seamen, to whom it would be the most useful, and for whom it was principally wanted. The Secretary of State is therefore of opinion that, since the subject has been brought under observation, it should be made the occasion of disseminating its knowledge generally and effectually among seafaring citizens of the United States. The following is one of the many methods which might be proposed for doing this:

Let the clearance for every vessel sailing from the ports of the United States be printed on paper, on the back whereof shall be a printed account of the essays which have been made for obtaining fresh from salt water, mentioning briefly those which were unsuccessful, and, more fully, those which have succeeded; describing the methods which have been found to answer for constructing extempore stills of such implements as are generally on board of every vessel, with a recommendation, in all cases where they shall have occasion to resort to this expedient for obtaining water, to publish the result of their trial in some gazette on their return to the United States, or communicate it for publication to the office of the Secretary of State, in order that others may, by their success, be encouraged to make similar trials, and be benefited by any improvements or new ideas which may occur to them in practice.

THOMAS JEFFERSON.

PHILADELPHIA, Nov. 21, 1791.

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EXHIBIT 7

## DEPARTMENT OF THE INTERIOR DEPARTMENTAL MANUAL

ORGANIZATION SERIES—PART 111, OTHER DEPARTMENTAL UNITS

September 16, 1955 (replaces April 6, 1955)

### CHAPTER 7—OFFICE OF SALINE WATER

1. *Functions.*—The Office of Saline Water, under the supervision of the Assistant Secretary, Water and Power Development, performs functions vested in the Secretary of the Interior by the act of July 3, 1952, as amended by the act of June 29, 1955, which were enacted to provide for research into and development of practical means for the economical production, from sea or other saline water, of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses. This purpose is carried out by means of research grants and contracts made to or with chemists, physicists, engineers, educational institutions, scientific organizations, or industrial or engineering firms, to conduct research and technical development work. The Office performs the following specific functions:

A. Formulates and maintains currently a productive research and development program of national and international scope for the economic conversion of saline water by stimulating private research and sponsoring Governmental research; determines the needs of industry, agriculture, and municipalities for saline-water conversion, and the types and quantities of converted water required; and plans research and development activities to meet these needs.

B. Coordinates and exchanges information on saline-water conversion research, private and governmental; prepares publicity and information on the subject; plans and manages meetings and symposia; coordinates and integrates results of its activities with private and other related activities of the Department of Defense, National Science Foundation, Atomic Energy Commission, Smithsonian Institution, Federal Civil Defense Administration, Department of Agriculture, Department of State, and the Department of Commerce.

C. Prepares, negotiates, and supervises research and development contracts and grants; and determines which scientific organizations and individuals are equipped to conduct research or development work, which processes should be emphasized or curtailed or the direction which each should take, in connection with:

(1) Investigation of new theories, principles, and phenomena of an exploratory nature embracing any field of science of potential use in applying developments, but without regard to the economics and processes.

(2) Applied research and development of practical applications with production of devices, systems, materials, and processes, including pilot plants, cost estimates, designs, and product engineering, with complete regard for all economic factors.

2. *Organization.*—The Office of Saline Water, under a Director, has the following organizational components:

A. *Office of the Director.*—The office of the Director plans and directs the research and development program, and supervises the coordination and ex-

change of information and the negotiation and preparation of contracts or grants. It is responsible for all administrative activities performed in the Office of Saline Water, which includes the preparation of budget estimates and their presentation to the Division of Budget and Finance.

B. *Branch of Coordination.*—The Branch of Coordination coordinates and exchanges information on all saline-water conversion research, past, present, and planned; prepares publicity and information, including technical and annual reports; plans and manages meetings and symposia; makes surveys of saline-water resources and potential uses; and coordinates activities with other governmental agencies.

C. *Branch of Research.*—The Branch of Research directs research through grants and contracts to an increase of knowledge in science for potential use in saline-water conversion. Such research is fundamental in nature, and may embrace any field of science by means of theoretical studies or laboratory investigations. The Branch directs research through grants and contracts in practical applications of science to the problems of saline-water conversion. Such research is applied in nature. It is particularly concerned with laboratory investigations and the determination of preliminary findings relating to establishment of technical and economic feasibility of new or improved processes.

D. *Branch of Development and Engineering.*—The Branch of Development and Engineering develops, through grants and contracts, practical use of scientific knowledge for applications to the production of devices, systems, materials, or processes, capable of converting saline water to fresh water at reasonable cost. Engineering work performed includes advanced developmental investigations, working units, pilot plants and field testing, cost estimates, designs, and production engineering, with complete cognizance of all economic factors.

3. *Supporting Services and Advice.*—With respect to the review and analysis of proposals from applicants for research grants or contracts, and the results of work accomplished under such contracts, the Office of Saline Water utilizes the services of specialized scientists and engineers, both private, parti-time consultants and those in Government agencies, including bureaus of the Department. Representatives of the Bureau of Mines, the Bureau of Reclamation, and the Geological Survey, under the chairmanship of a representative of the Assistant Secretary, Water and Power Development, constitute the Saline Water Conversion Committee. This Committee assists in the development and review of the program, exchange of information and coordination of activities in connection with the program, and the preparation of the annual report. In addition, a group of leaders of educational, industrial, and scientific organizations, serving as members of the Saline Water Advisory Board, provide advice to the Secretary on the economic, social, and policy matters of broad scope relating to the program.

## Exhibit 8

### Office of Saline Water

*Research and development contracts*

| Contractor | Title | Amount | Duration | Remarks |
|---|---|---|---|---|
| Ionics, Inc. | Demineralizing saline waters by electrodialysis | $30,000.00 | Jan. 16 to Aug. 16, 1953 | Exploratory study. |
| Battelle Memorial Institute | Research investigations of multiple-effect evaporation of saline water by steam from solar radiation. | 3,339.85 | June 17 to Dec. 17, 1953 | Not promising. |
| Heinz Engineering Co. | Determining the feasibility of further developing the compression distillation process for the demineralization of sea water on a large scale at low cost. | 19,980.00 | June 17, 1953, to May 1, 1955 | Exploratory study. |
| Dr. G. O. G. Löf | Engineering survey and evaluation of possible methods for demineralization of sea and other saline waters by use of solar energy. | 6,235.00 | June 30, 1953, to Apr. 1, 1954 | A survey. |
| South Dakota School of Mines | Inventory of published and unpublished data on the characteristics of saline surface and ground waters of South Dakota. | 6,390.00 | June 30, 1953, to June 30, 1954 | A preliminary study. |
| University of Florida | Synthetic osmotic membranes for demineralization of sea and other saline waters. | 19,510.00 | June 30, 1953, to Aug. 31, 1954 | Promising. |
| State University of New York | Determination of the probable proximity to the minimum energy requirement for producing fresh water from sea water which might be reached by various existing and potential separation processes. | 35,041.00 | June 30, 1953, to Sept. 1, 1956 | Preliminary study. |
| Yale University | Research on the improvement of heat-transfer rates in condenser-boilers of vapor-compression evaporators directed to cost reduction of large-scale demineralization of saline water. | 16,330.00 | June 30, 1953, to Aug. 31, 1955 | Promising. |
| Texas A. and M. Research Foundation | Exploratory research on the applicability of a solvent-extraction process to the economical demineralization of salt water. | 12,837.50 | July 10, 1953, to Mar. 1, 1955 | Do. |
| University of Minnesota | Development of a comprehensive working procedure for making a survey of waste heat potentially applicable to large-scale, low-cost demineralization of saline water. | 8,280.00 | July 10, 1953, to Aug. 1, 1954 | Preliminary study. |
| Polytechnic Institute of Brooklyn | Research on and development of ion-selective and ion-specific membranes for use in the large-scale, low-cost demineralization of saline waters by selective electrodialysis. | 52,840.00 | Oct. 29, 1953, to Oct. 31, 1958 | In progress. |
| Nuclear Development Corp. | Research to determine suitable conditions for the extraction of fresh water from sea water in the supercritical state. | 37,430.00 | Jan. 4 to Oct. 31, 1954 | Promising. |
| Bjorksten Research Laboratories | Research on and development of plastics solar stills for use in the large-scale, low-cost demineralization of saline waters by solar evaporation. | 33,900.00 | Mar. 8, 1954, to Nov. 15, 1955 | Do. |
| Badger Manufacturing Co. | Development and design of the Hickman vapor-compression still. | 115,000.00 | Apr. 6, 1954, to Oct. 5, 1955 | Do. |
| Ionics, Inc. | Design, construction, and field test of experimental membrane demineralization unit. | 148,635.00 | Apr. 7, 1954, to Apr. 15, 1956 | Do. |
| University of California (Los Angeles) | Research and development of molecular oil films for use in the large-scale, low-cost demineralization of saline waters by a pressure method. | 20,500.00 | Apr. 16, 1954, to June 30, 1956 | Current support by University of California. |

## OFFICE OF SALINE WATER—Continued

*Research and development contracts*—Continued

| Contractor | Title | Amount | Duration | Remarks |
|---|---|---|---|---|
| New York University (M. Telkes) | New and improved methods for lower cost solar distillation | $31,905.00 | June 25, 1954, to July 30, 1957 | Promising. |
| Applied Sciences Laboratories | Research on salt-water purification by freezing | 19,493.00 | June 25, 1954, to Aug. 31, 1955 | Do. |
| University of Florida | Investigation of possible use of ultrasonics in the demineralization of saline waters. | 4,945.00 | Oct. 4, 1954, to May 15, 1955 | Not promising. |
| Do | Process development of a desalting method using synthetic osmotic membranes. | 44,060.00 | Nov. 16, 1954, to Aug. 15, 1958 | In progress. |
| W. L. Badger | Determining probable cost of large-scale demineralization of saline water by combined thermocompression and multiple-effect cycles. | 6,500.00 | Dec. 7, 1954, to June 7, 1955 | Promising. |
| University of Washington | Research and development of processes for desalting sea water by freezing. | 19,580.00 | Dec. 16, 1954, to May 31, 1956 | Not promising. |
| Dr. G. O. G. Löf | Design and evaluation of simple, inexpensive, solar distillation units for demineralizing saline waters. | 16,530.00 | Dec. 28, 1954, to June 30, 1957 | Promising. |
| Nuclear Development Corp | Research and development in the extraction of fresh water from sea water in the critical or near-critical state. | 83,260.00 | Jan. 1, 1955, to Apr. 15, 1957 | Needs new approaches. |
| Allied Industries | Experiments to determine whether saline water can be demineralized by application of an ultrahigh electrical field. | 1,000.00 | Jan. 27 to June 27, 1955 | Not promising. |
| Texas A. and M. Research Foundation | Research on the solvent demineralization of saline waters | 50,205.00 | May 11, 1955, to Oct. 1, 1957 | Promising. |
| University of Iowa | Research on demineralization of saline waters by pressure permeation through microporous membranes. | 10,000.00 | June 27, 1955, to Nov. 30, 1957 | Not promising. |
| University of Florida | Research on water and ion flow through imperfect osmotic membranes. | 14,061.00 | June 27, 1955, to Oct. 31, 1957 | Promising. |
| Battelle Memorial Institute | Evaluation of the zone-purification process as a method of preparation of potable water from sea water. | 46,000.00 | June 30, 1955, to Mar. 31, 1958 | Do. |
| Badger Manufacturing Co | Research, design, and construction of Badger-Hickman type vapor-compression saline-water distilling equipment. | 245,213.00 | Sept. 30, 1955, to Aug. 15, 1957 | Do. |
| Applied Science Laboratories | Exploratory research on salting out natural salts from sea water | 7,985.00 | Jan. 16, 1956, to Aug. 31, 1957 | Not promising. |
| Armour Research Foundation | Evaluation of a partial pressure distillation process for saline-water conversion. | 5,700.00 | May 22 to Nov. 22, 1956 | Do. |
| W. L. Badger | Plans, specifications, and test procedures for investigating sea-water scale prevention in long-tube vertical evaporators. | 11,500.00 | June 4 to Dec. 30, 1956 | Promising. |
| Applied Science Laboratories | Research on increase in saline ice-crystal dimensions and on flotation methods for separating entrained salt from saline ice. | 14,484.00 | June 4, 1956, to Sept. 4, 1957 | Do. |
| Carrier Corp | Research on and analysis of certain conversion processes utilizing refrigeration principles. | 110,138.00 | June 4, 1956, to Oct. 31, 1958 | Do. |
| South Dakota School of Mines | Investigation of the availability of geothermal energy for the demineralization of saline water. | 11,435.00 | June 27, 1956, to Sept. 30, 1957 | Preliminary study. |
| Southern Research | Development, construction, and testing of osmionic demineralizers. | 48,678.00 | June 28, 1956, to Feb. 15, 1958 | Promising. |
| Battelle Memorial Institute | Investigation of the availability of geothermal energy for the demineralization of saline water. | 10,000.00 | June 29, 1956, to July 31, 1957 | Preliminary study. |

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| Griscom-Russell | Research on and analysis of single-effect, low-temperature, flash-evaporation processes. | 30,000.00 | Oct 24, 1956, to Nov. 30, 1957 | Promising. |
| Bjorksten Research Laboratories | Evaluation of plastics films for use in solar stills | 10,945.00 | Oct. 29, 1956, to Mar. 29, 1958 | In progress. |
| Dr. Louis Koenig | An orientation study on disposal of saline-water conversion brines. | 3,300.00 | Dec. 11, 1956, to Apr. 11, 1957 | Preliminary study. |
| Whiting Corp | Establishing an experimental facility for research on sea-water scale control and prevention in long-tube vertical evaporators. | 155,000.00 | Dec. 28, 1956, to Mar. 28, 1958 | In progress. |
| National Academy of Sciences | Cooperative arrangement for planning and conducting a scientific symposium on saline-water conversion. | 17,040.00 | Feb. 13, 1957, to Feb. 13, 1958 | Do. |
| Dr. Horace G. Deming | An investigation of transport depletion as a means of demineralizing saline water. | 4,055.00 | Mar. 12, 1957, to Mar. 15, 1958 | Do. |
| Resources Research | Survey of physiological mechanisms of sodium and chloride ion transport and design of experiment for application to demineralizing saline waters. | 5,000.00 | Mar. 25 to Sept. 25, 1957 | Exploratory survey. |
| Fluor Corp | Study of the applicability of combining nuclear energy with saline-water distillation processes. | 36,835.00 | May 8, 1957, to Feb. 8, 1958 | In progress. |
| University of Oklahoma | Investigation of electrical control of adsorptivity of porous conductors having large surface area and its use in saline-water demineralization. | 16,626.00 | June 6, 1957, to June 6, 1958 | Do. |
| W. L. Badger | Comprehensive literature survey on scale formation from sea water. | 13,500.00 | June 13, 1957, to Jan. 31, 1958 | Preliminary study. |
| Badger Manufacturing Co | Disassembly, shipment, and reassembly of Badger-Hickman distillation units. | 32,915.00 | Aug. 28, 1957, to Jan. 28, 1958 | In progress. |
| B. F. Dodge | Economic evaluation study of distillation of saline water by means of forced-circulation, vapor-compression, distillation equipment. | 4,700.00 | Sept. 26, 1957, to May 26, 1958 | Do. |
| New York University | Development of new types of solar stills | 6,500.00 | Oct. 8, 1957, to Feb. 8, 1958 | Do. |
| Dr. K. C. D. Hickman | Evaluation of rotary-barrier distillation saline-water conversion process developments. | 7,500.00 | Oct. 31, 1957, to July 31, 1958 | Do. |
| Battelle Memorial Institute | Further research and development program on the Badger-Hickman water-distillation process. | 75,000.00 | Nov. 13, 1957, to Nov. 13, 1958 | Promising. |
| Alpine Laboratories, Inc | Experiments to determine whether saline water can be demineralized by application of an ultra-high-frequency electrical field. | 2,500.00 | Dec. 9, 1957, to Mar. 9, 1958 | In progress. |
| Texas A. and M. Research Foundation | Development of the solvent demineralization of saline water | 25,000.00 | Oct. 1, 1957, to Oct. 1, 1958 | Do. |
| Cornell University | Research on and analysis of desalting of saline water by continuous crystallization. | 14,875.00 | Dec. 31, 1957, to Sept. 30, 1959 | Do. |
| Battelle Memorial Institute | Establishment of solar distillation field experimental program | 55,000.00 | Dec. 31, 1957, to Dec. 31, 1958 | Do. |

EXHIBIT 9

COOPERATIVE AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE STATE OF CALIFORNIA FOR MUTUAL ASSISTANCE IN THE PROBLEM OF SALINE WATER CONVERSION

This agreement is entered into pursuant to the act of July 3, 1952 (66 Stat. 328, 42 U. S. C., sec. 1951) as amended by the act of June 29, 1955 (69 Stat. 198, 42 U. S. C., sec. 1958) and the Interior Department Appropriation Act 1958 (Public Law 85–77, 85th Congress, 71 Stat. 257) between the United States of America, hereinafter called the Government, represented by the contracting officer and the State of California, hereinafter referred to as the State, represented by the Director of Water Resources.

Whereas the Government in the course of research into the development of practical means for the economical production from sea water, or from other saline waters, of water suitable for consumptive uses on a scale sufficient to determine the feasibility of the development of such production and distribution on a large-scale basis desires a cooperative effort with the State on problems of mutual interest; and

Whereas the State has proposed such a cooperative agreement suggesting in general terms the objectives and overall procedure for the cooperation; and

Whereas a knowledge of the natural resources, specific conditions and problems facing the State in connection with its water problems will be helpful to the Office of Saline Water of the United States Department of the Interior in its future planning; and

Whereas the Office of Saline Water has acquired considerable technical information and is continuing to acquire such information, which is of a nature that would not ordinarily be published, but would be of benefit to the State of California,

Now therefore it is mutually agreed that:

1. There shall be maintained until June 30, 1960, unless terminated earlier by mutual agreement, mutual assistance and exchange of information on the programs of each relating to water problems in general, and to techniques and economics of saline water conversion in particular. The termination date of June 30, 1960, may be extended by mutual agreement.

2. Information exchanged between both parties by correspondence and personal interviews shall include but not necessarily be limited to:

(*a*) Technical information, on research and development of improved saline water conversion processes and their actual or potential application.

(*b*) Technical advice and assistance on problems of mutual interest to the extent mutually agreed upon from time to time.

(*c*) Potential demand for converted water, present and future, to the extent that such information is available.

3. It is understood that, unless mutually agreed otherwise, the technical information exchanged will be limited to that of a nonconfidential nature.

4. Neither party will publish data obtained as a result of this cooperative effort without first obtaining the written approval of the other.

5. Expenses incurred in the performance of this investigation shall be paid by the party incurring the expense. Such expenses being governed by the laws and regulations respectively governing each party.

This cooperative agreement shall become effective upon the day it is signed by the contracting officer.

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES,
By HARVEY O. BANKS,
*Director of Water Resources.*

MARCH 27, 1958

THE UNITED STATES OF AMERICA,
By FRED G. AANDAHL,
*Assistant Secretary for Water and Power.*

APRIL 18, 1958

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